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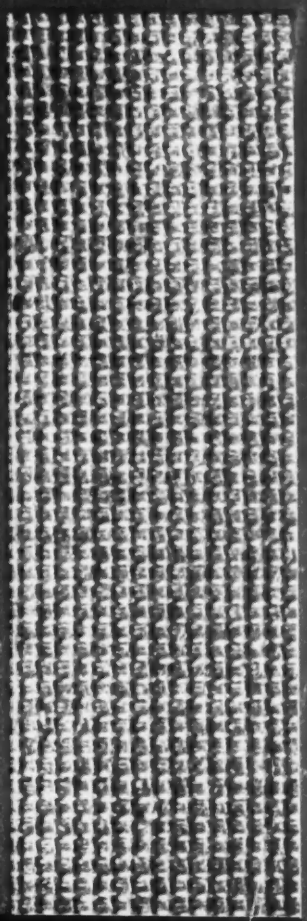
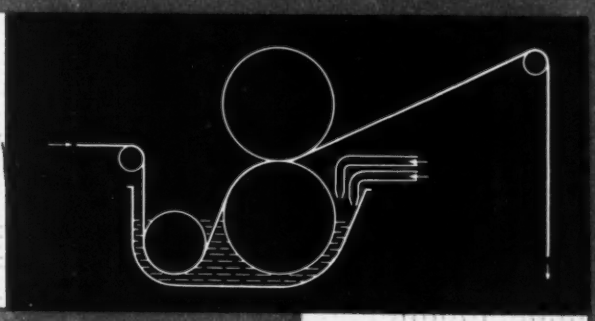
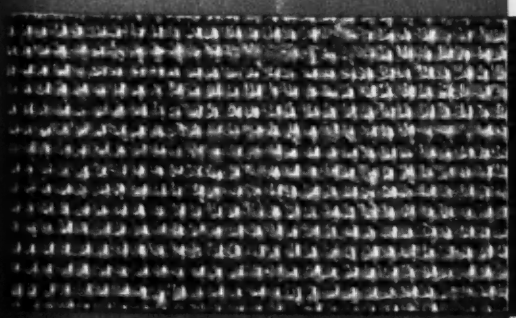
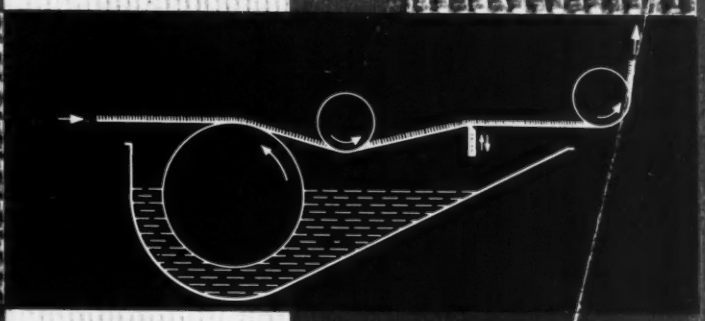


...matic control of impregnating and coating processes, p.84

Applications described include pre-weave warp-yarn sizing, cloth finishing, carpet back sizing, paper coating, plastics impregnation, tissue and fleece bonding, adhesive deposition for abrasive sheet, and galvanizing steel strip







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JUNE 1961 MONTHLY 3/6

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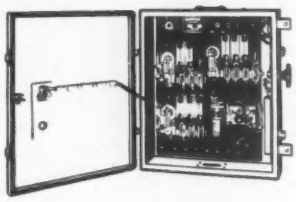

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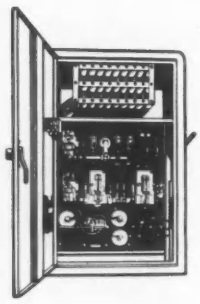

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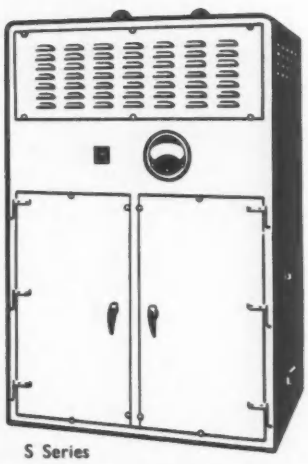

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CONTROL

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VOL 4 NO 36 JUNE 1961

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LOOKING FOR A JOB? Control *carries the best jobs in instrument and control engineering.* **SEE PAGE 192 AND ONWARDS**

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LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.A.C., British Conference on Automation and Computation. B.C.S., British Computer Society. Brit.I.R.E., British Institution of Radio Engineers. I.C.E., Institution of Civil Engineers. I.Chem.E., Institution of Chemical Engineers. I.E.E., Institution of Electrical Engineers. I.Mech.E., Institution of Mechanical Engineers. I.Prod.E., Institution of Production Engineers. I.S.A., Instrument Society of America. R.Ae.S., Royal Aeronautical Society. S.B.A.C., Society of British Aircraft Constructors. S.I.T., Society of Instrument Technology.

FRIDAY 9—SATURDAY 17 JUNE
13th Chemical Engineering Exhibition and Congress, Frankfurt am Main. Details: Dechema, Decheme-Haus, Rheingau-Allee 25, Frankfurt am Main, Germany.

MONDAY 12 JUNE
Air Pollution Instrumentation Symposium (with the June 12–16 annual meeting of the Air Pollution Control Association), Hotel Commodore, New York City, N.Y., U.S.A. Sponsors: I.S.A. and A.P.C.A. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

MONDAY 12—THURSDAY 15 JUNE
British Electrical Power Convention: *Electricity in the prosperity and welfare of the nation.* Details: Electrical Development Association, 2 Savoy Hill, W.C.2.

WEDNESDAY 12—FRIDAY 16 JUNE
Computers and production technology; a summer school at the Northampton College of Advanced Technology. Details: The Secretary, Northampton College, St John St, E.C.1.

MONDAY 12—SATURDAY 17 JUNE
Conference on *Components and materials used in electronic engineering.* Central Hall, Westminster, S.W.1. (*I.E.E.*)

TUESDAY 13—FRIDAY 16 JUNE
3rd Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

WEDNESDAY 14 JUNE
The 1961 Viscount Nuffield Paper: *Some aspects of engineering progress*, by Sir Willis Jackson. 6.30 p.m. Bristol University (*I.Prod.E.*)

THURSDAY 15—FRIDAY 16 JUNE
Two open days at Bisra's Sheffield Laboratories. Details: D. U. Hunt, B.I.S.R.A., 11 Park Lane, London, W.1.

THURSDAY 15—SATURDAY 24 JUNE
International Construction Equipment Exhibition, Crystal Palace. Details: J. Brewster, I. and T. F. Ltd, Commonwealth House, New Oxford St, W.C.1.

MONDAY 19—FRIDAY 23 JUNE
6th International Instrument Show, 4 Tilney St, Park Lane, W.1. Sponsors: B. & K. Laboratories.

WEDNESDAY 20—THURSDAY 28 JUNE
Third Congress of the European Federation of Chemical Engineering, Olympia. Details: The General Secretary, Society of Chemical Industry, 14 Belgrave Sq., S.W.1.

MONDAY 26—WEDNESDAY 28 JUNE
European Symposium on Space Technology. Details: L. J. Carter, Secretary, British Interplanetary Society, 12 Bessborough Gdns, S.W.1.

MONDAY 26 JUNE—SATURDAY 1 JULY
International Measurements Conference, (Imeko), Budapest. Details: J. F. Coales, Cambridge University, Trumpington St, Cambridge, or Imeko Secretariat, Budapest 5, P.O.B. 3, Hungary.

TUESDAY 27—FRIDAY 30 JUNE
A conference on *The social and economic effects of automation*, sponsored by members of the B.C.A.C. Applications for tickets to The British Institute of Management, 80 Fetter Lane, E.C.4.

WEDNESDAY 28—FRIDAY 30 JUNE
2nd Joint Automatic Control Conference. University of Colorado, Boulder, Colo., U.S.A. Sponsors: I.S.A., A.I.Ch.E., A.I.E.E., A.S.M.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

WEDNESDAY 5—SATURDAY 9 JULY
Radio techniques and space research. A convention at Oxford University. (*Brit. I.R.E.*)

FRIDAY 7—SATURDAY 29 JULY
Russian Trade Fair, Earls Court. Details: Industrial and Trade Fairs Ltd, Drury House, Russell St, Drury Lane, W.C.2.

SUNDAY 16—FRIDAY 21 JULY
4th International Conference on *Medical electronics* at the Waldorf-Astoria, New York. Sponsors: I.R.E., A.I.E.E., I.S.A. Details: Institute of Radio Engineers, 1 East 79th St, New York City, N.Y., U.S.A.

TUESDAY 1—SATURDAY 12 AUGUST
Sydney Trade Fair, Sydney, N.S.W., Australia. Details: Press Office, Commonwealth House, New Oxford St, London, W.C.1.

LOOKING FURTHER AHEAD

WED. 30 AUGUST—WED. 6 SEPTEMBER
Annual Meeting, British Association for the Advancement of Science, Norwich. Details: Secretary, B.A.A.S., 19 Adam St, Strand, London, W.C.2.

MONDAY 4—SATURDAY 9 SEPTEMBER
3rd International Session of the International Association for Analogue Computation. Belgrade, Yugoslavia. Details: Yugoslav Committee for Etan, Terazije, 23/VII, Belgrade, Yugoslavia.

MONDAY 4—SUNDAY 10 SEPTEMBER
S.B.A.C. Flying display and exhibition, Farnborough. Details: S.B.A.C., 29 King St, St James's, London, S.W.1.

TUESDAY 5—FRIDAY 8 SEPTEMBER
An international conference on *Machine translation of language and applied language analysis.* National Physical Laboratory, Teddington, Middlesex. Papers to Dr A. M. Uttley, Autonomics Div., N.P.L.

WEDNESDAY 6—FRIDAY 8 SEPTEMBER
International Symposium on *Transmission and processing of information.* Massachusetts Institute of Technology. Submission of papers is invited. Details: R. M. Fano, R.L.E., M.I.T., Cambridge, 39, Mass., U.S.A.

Joint Nuclear Instrumentation Symposium. North Carolina State College, Raleigh, N.C., U.S.A. Sponsors: I.S.A., A.I.E.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

MONDAY 11 SEPTEMBER
20th International Congress of Navigation. Baltimore. Details: Permanent International Association of Navigation Congresses, 60 rue Juste Lipse, Brussels, Belgium.

MONDAY 11—FRIDAY 15 SEPTEMBER
I.S.A. Instrument-Automation Conference and Exhibition and I.S.A.'s 16th Annual Meeting. Memorial Sports Arena, Los Angeles, Calif., U.S.A. Details: Wm H. Kushnick, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

Third International Congress on Cybernetics, Namur, Belgium. Details: Association Internationale de Cybernétique, 13, rue Basse-Marcelle, Namur, Belgium.

MONDAY 18—FRIDAY 22 SEPTEMBER
Symposium on *Network theory*, Cranfield. Details: S.R. Deards, Department of Electrical and Control Engineering, The College of Aeronautics, Cranfield, Bletchley, Bucks.

TUESDAY 26 SEPTEMBER—FRIDAY 6 OCTOBER
International Heating, Ventilating and Air-conditioning Exhibition, Olympia. (A conference will run concurrently from Wednesday 27 September — Wednesday 4 October.) Sponsors: Institution of Heating and Ventilating Engineers.

WEDNESDAY 4—THURSDAY 12 OCTOBER
Second Electronic Computer Exhibition and Symposium, London. Details: Mrs S. S. Elliott, 64 Cannon St, E.C.4.

THURSDAY 5—FRIDAY 6 OCTOBER
Two-day export conference. Details: C. G. E. Parrot, Overseas Div., B.E.A.M.A., 36 Kingsway, W.C.2.

THURSDAY 19 OCTOBER
The Thomson Lecture. An annual lecture on a general subject has been inaugurated by the S.I.T. The first, at 6 p.m. at the Royal Institution, is to be given by Sir George Thomson after whom the series is named. (*S.I.T.*)

WEDNESDAY 8—FRIDAY 10 NOVEMBER
Conference on *Non-destructive testing in electrical engineering.* (*I.E.E.*)

WEDNESDAY 13—MONDAY 18 NOVEMBER
Second Engineering Materials and Design Exhibition and Conference, Earls Court. Details: J. Brewster, Commonwealth House, New Oxford St, W.C.1.

WEDNESDAY 17—THURSDAY 18 JANUARY 1962
A symposium on *Electronic aids to banking*, under the aegis of B.C.A.C. Details: I.E.E.

TUESDAY 8—FRIDAY 18 MAY 1962
Mechanical Handling Exhibition, Earls Court. Details: H. A. Collman, Dorset House, Stamford St, S.E.1.

WEDNESDAY 20—TUESDAY 26 JUNE 1962
Third Congress of the European Federation of Chemical Engineering, Olympia. Details: The General Secretary, Society of Chemical Industry, 14 Belgrave Sq., S.W.1.

TUESDAY 14—THURSDAY 16 AUGUST 1962
Conference on *Standards and electronic measurements*, Boulder Laboratories of the National Bureau of Standards. Details: J. M. Richardson, Radio Standards Laboratory, National Bureau of Standards, Boulder, Colo., U.S.A.

THURSDAY 15—TUESDAY 20 OCTOBER 1962
International Congress and Exhibition of Laboratory, Measurement and Automation Techniques in Chemistry (Ilmac), Swiss Industries Fair, Basle, Switzerland. Details: M. Trottmann, Foire Suisse, d'Echantillons Basle, Switzerland.

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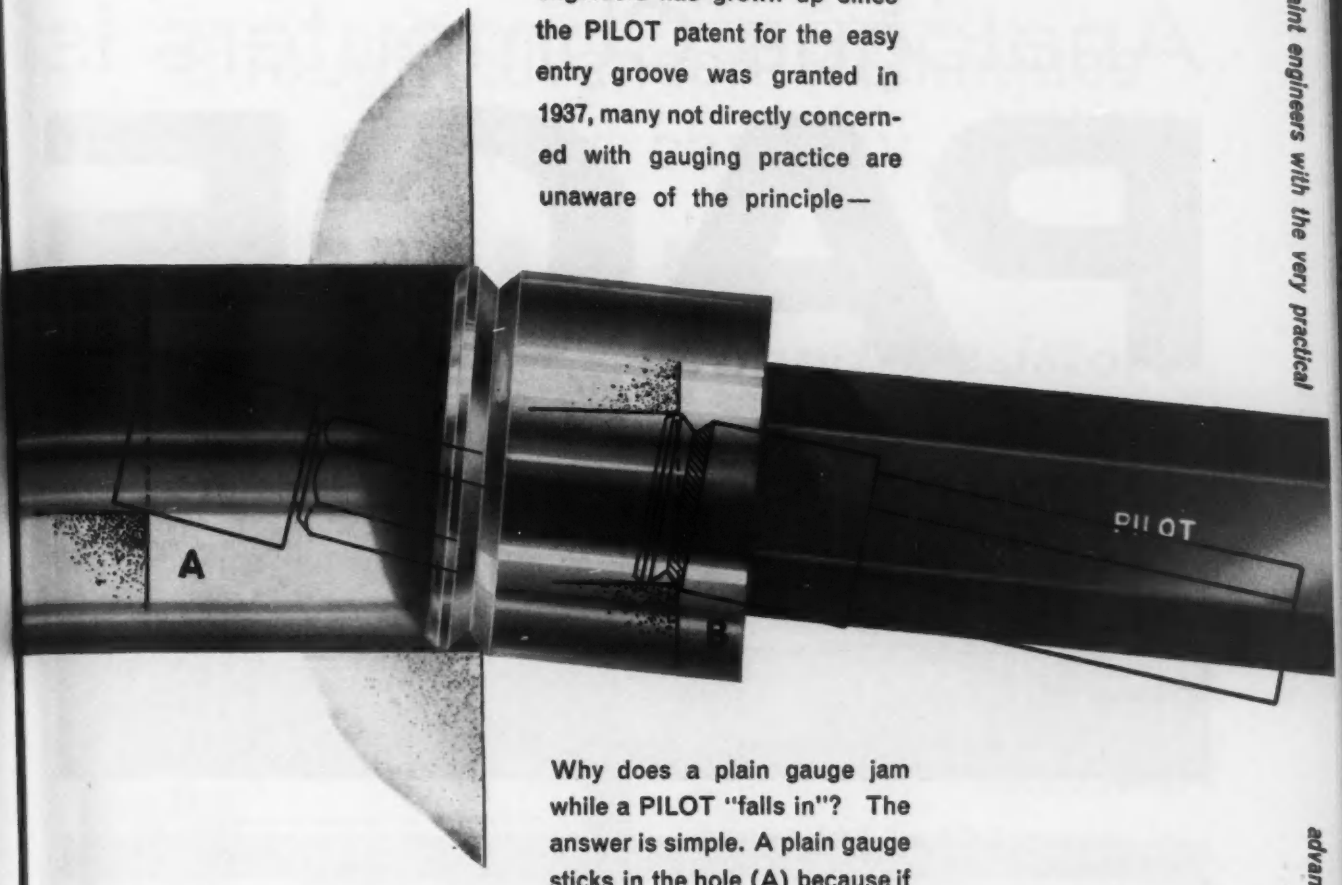

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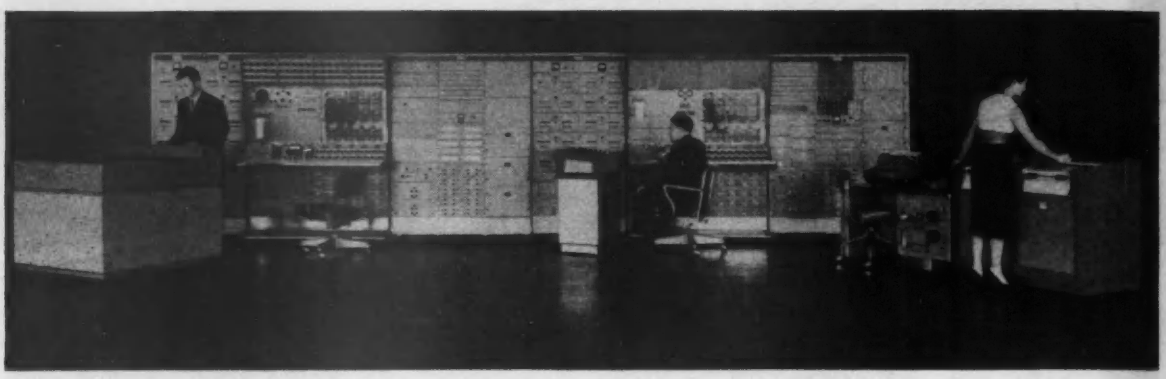

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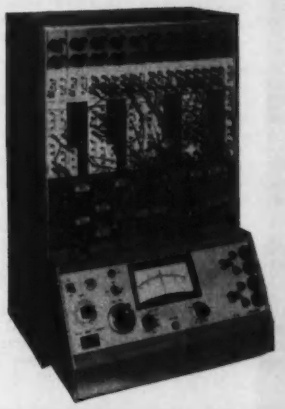

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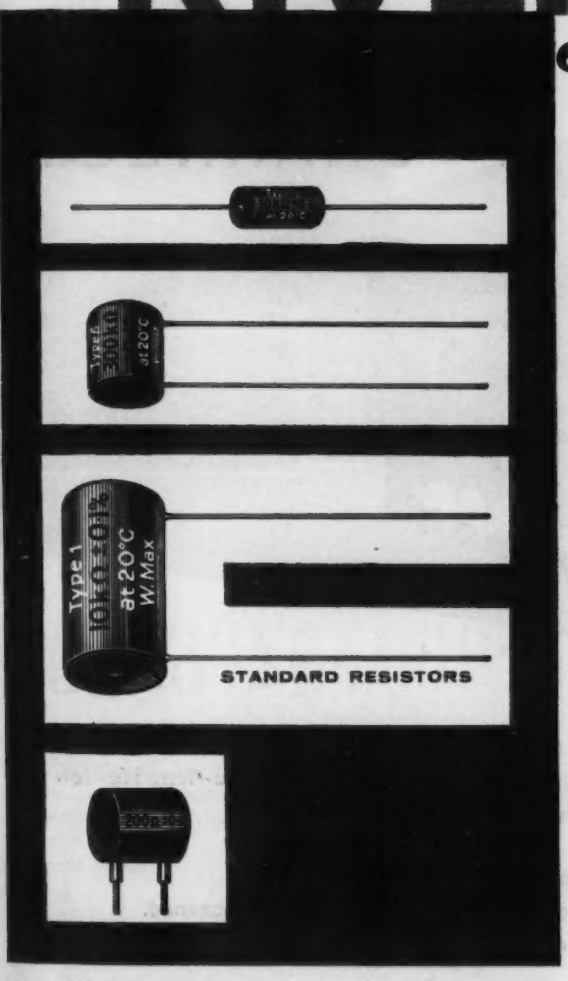

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10

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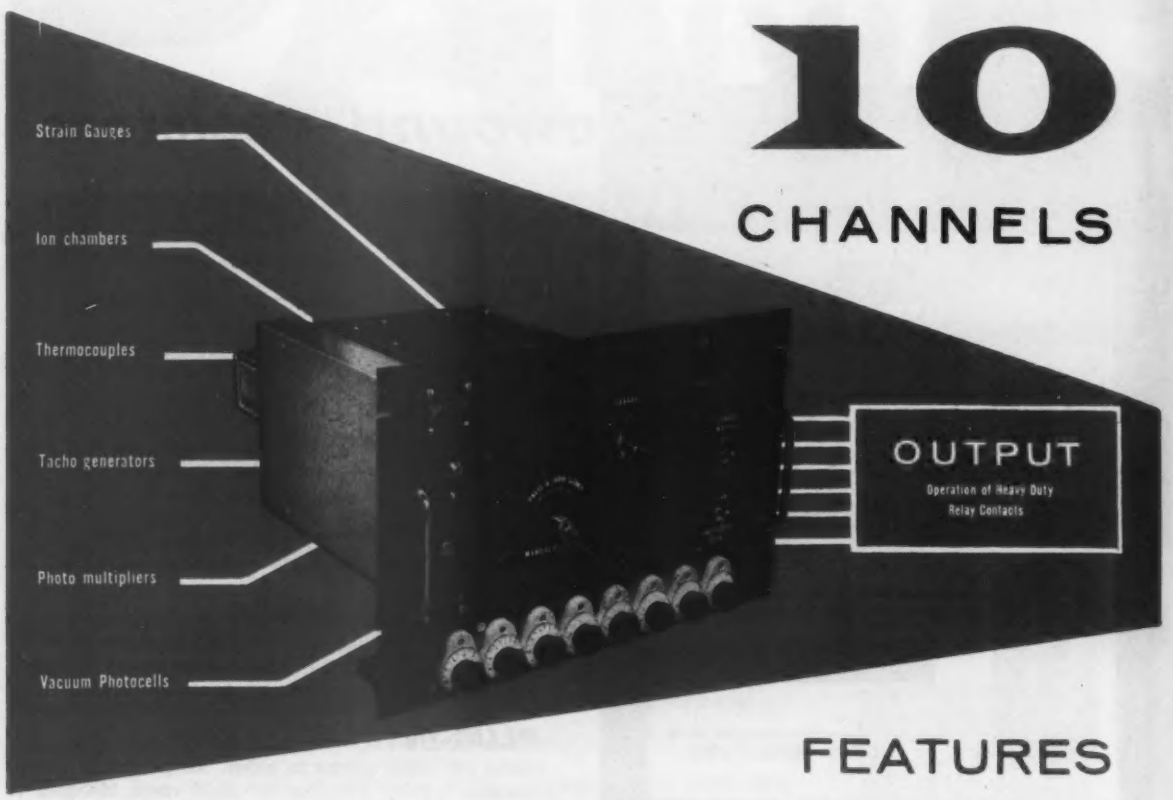

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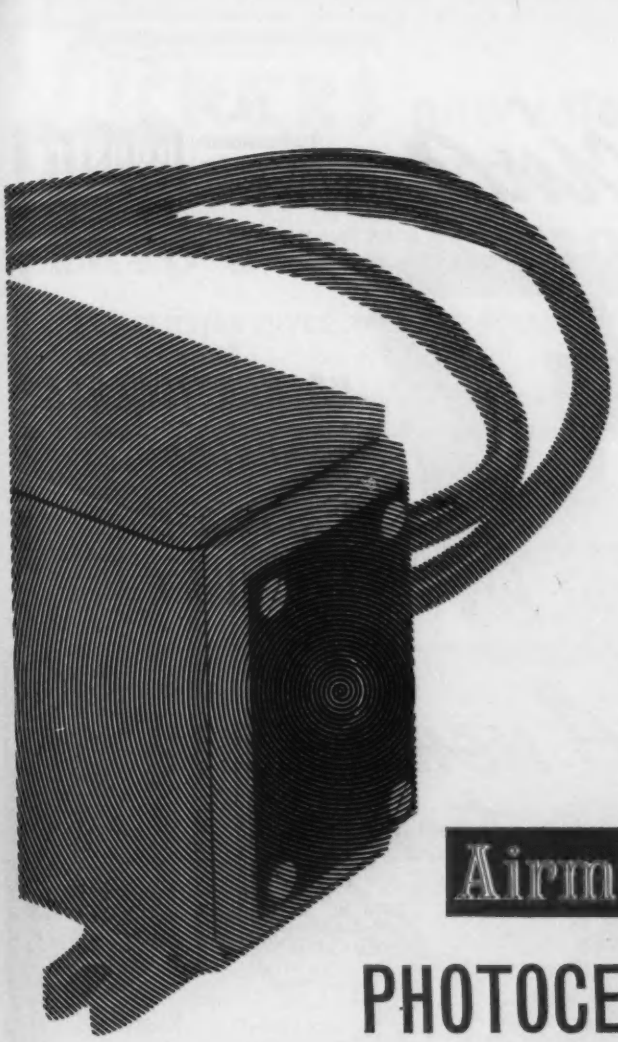

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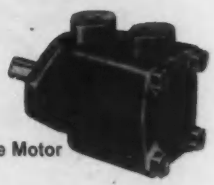
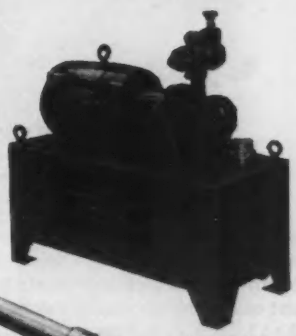


Vane-type Motor



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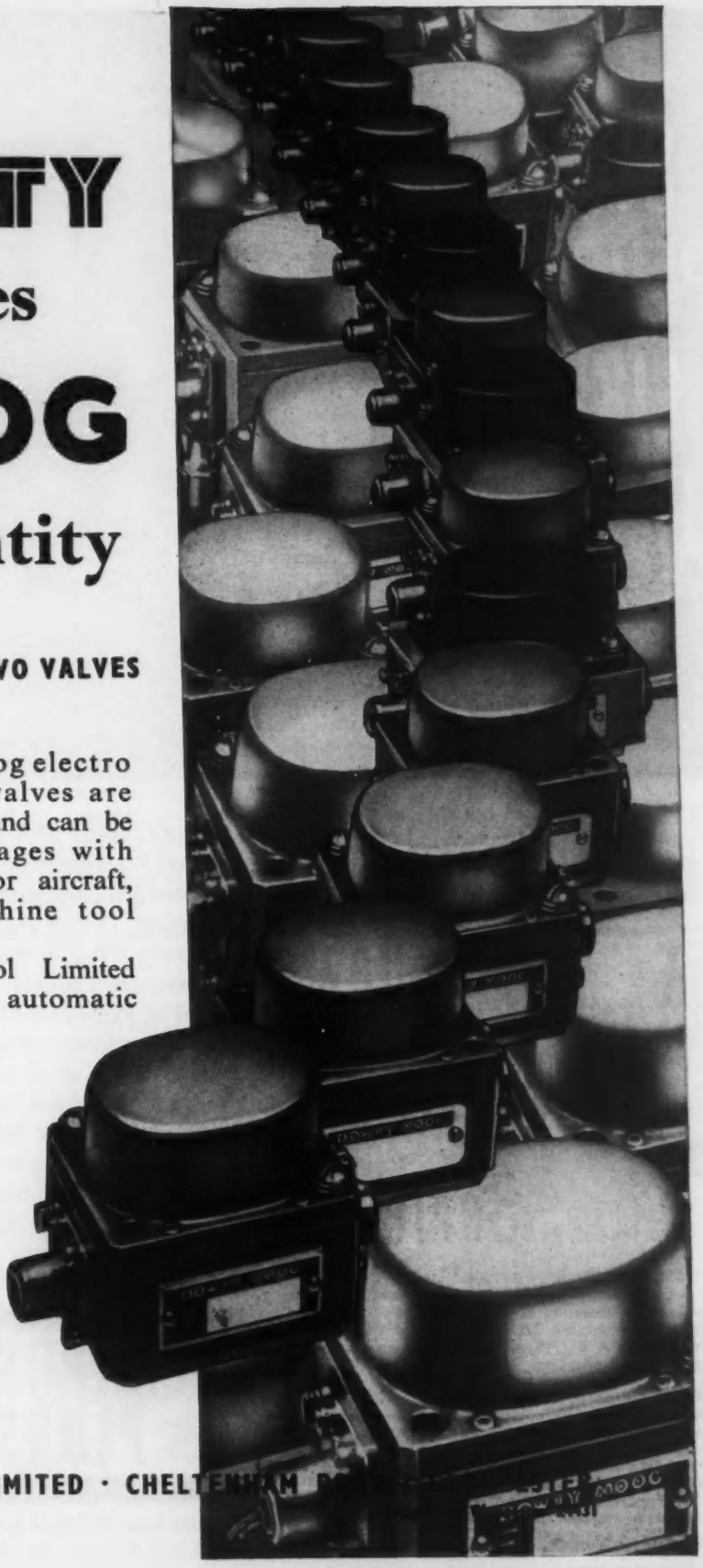

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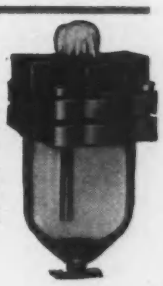

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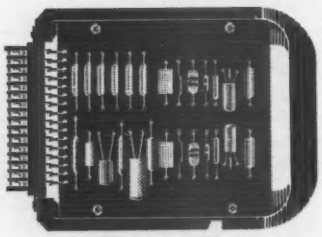
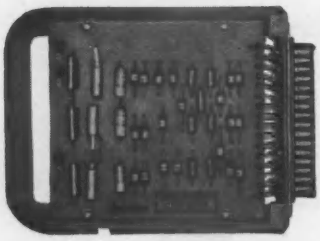
simply and economically achieved by 'DATAPACS'





'DATAPACS' are logical units designed and manufactured by 'ENGLISH ELECTRIC' and may be used in any required combination to form control systems. Using 'DATAPACS' as 'bricks', systems may be built for a variety of applications including:—

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Industrial Computation
Data Handling
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Each 'DATAPAC' is a modular package measuring 6 in. by 4 in. and comprises printed circuits, transistors and miniature components. The complete range covers more than 45 logical functions, thus offering considerable operational flexibility combined with economical system design.

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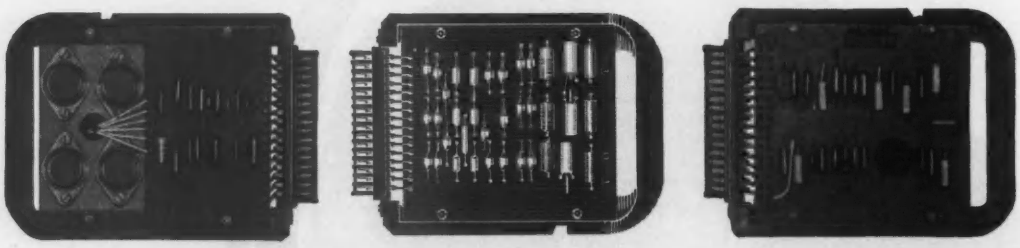

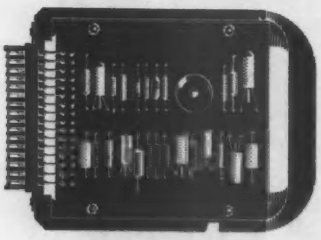

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the Company's name has been changed to
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SB1/2

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- BETA RANGE 5 TO 500.
- LEAKAGE CURRENT MEASUREMENTS (OUT OF CIRCUIT).
- BATTERY OPERATED TRULY PORTABLE.
- NET PRICE IN U.K. £40.

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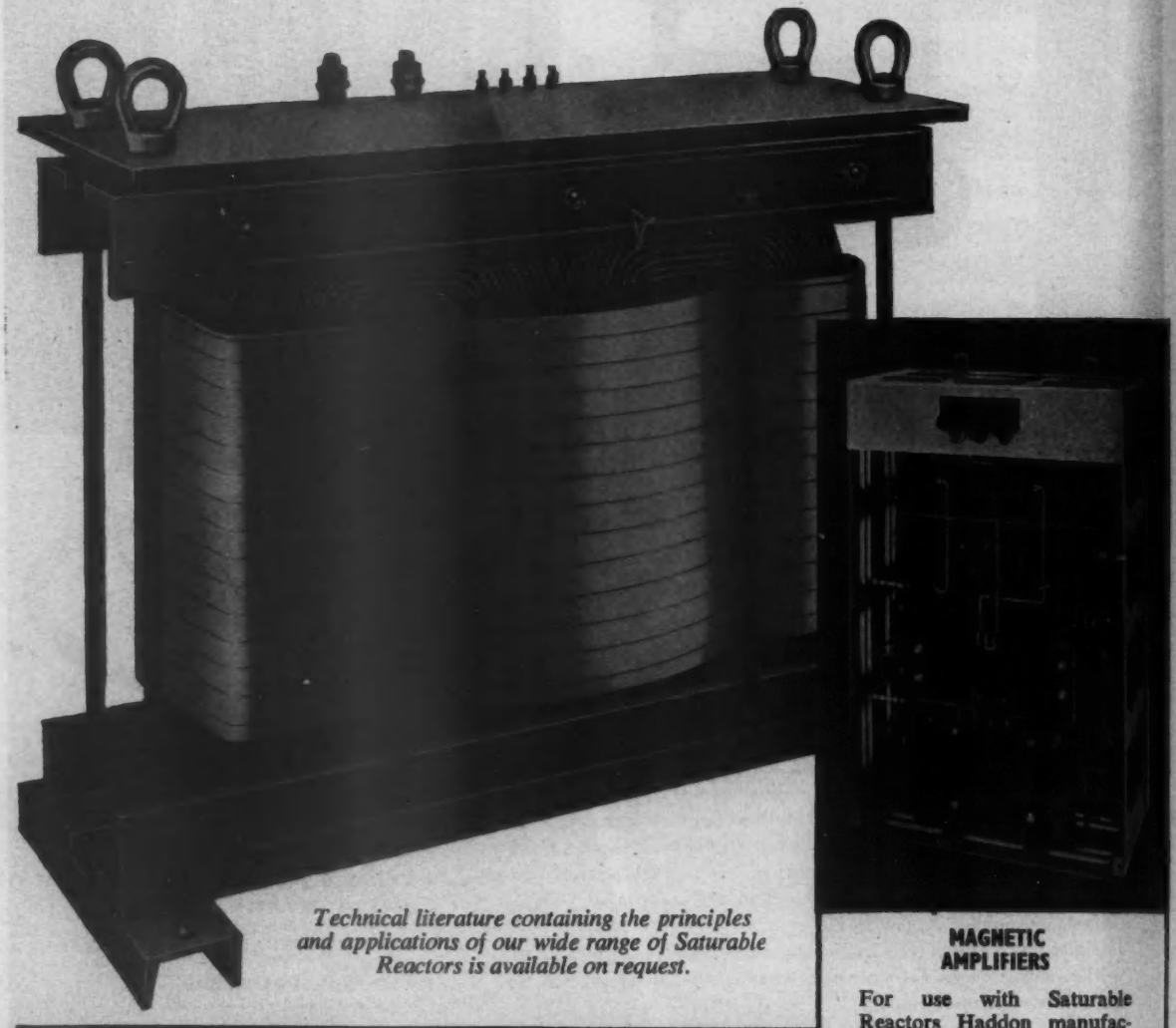
SATURABLE REACTORS
TRANSDUCTORS

Haddon **"STANDARD"** Saturable Reactors—Transductors operate from conventional A.C. line Voltages and provide a choice of D.C. Voltages for Control Windings. Selected from a wide range of individually designed and manufactured **SPECIALS** over past years, the **HADDON STANDARD RANGE** enable the discerning engineer to select **STANDARD EQUIPMENT** for Specific application. 416 standard single-phase designs cover the range 1 kVA to 300 kVA.

They provide the best method of stepless control in both long-term economies and high performance standard.



Technical literature containing the principles and applications of our wide range of Saturable Reactors is available on request.

HADDON

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- OUTPUT CONTINUOUSLY VARIABLE FROM 0 TO 50V.
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SBI/1

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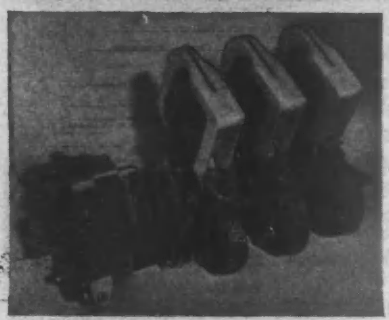
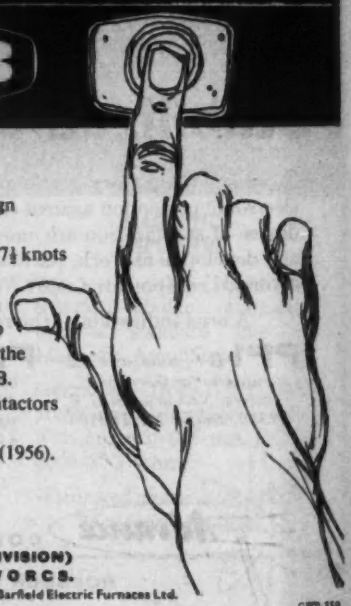
Acknowledgements to P & O Steam Navigation Co. Ltd., and Harland & Wolff, Ltd. Photograph by Central Press Photos Ltd.



C.522 500 A.M.P rated T.P. Contactor, fitted one normally open and one normally closed auxiliary contacts, as supplied for use as remote controlled isolators for part of the equipment supplied from each masterboard of the S.S. Canberra.

Some very advanced thinking went into the design of the giant P & O Liner S.S. Canberra. With accommodation for 2,235 passengers, its speed of 27½ knots will cut the London-Sydney run by six days. Accuracy and efficiency were essential—right down to the smallest component—and when it came to the operation of remote controlled isolators from the masterboards the contactors specified were GWB. Containing many unique features, all GWB Contactors are type tested and approved to category A.4, Mechanical Duty Class III and IV to B.S.S.775 (1956). Full details of the complete range on request.



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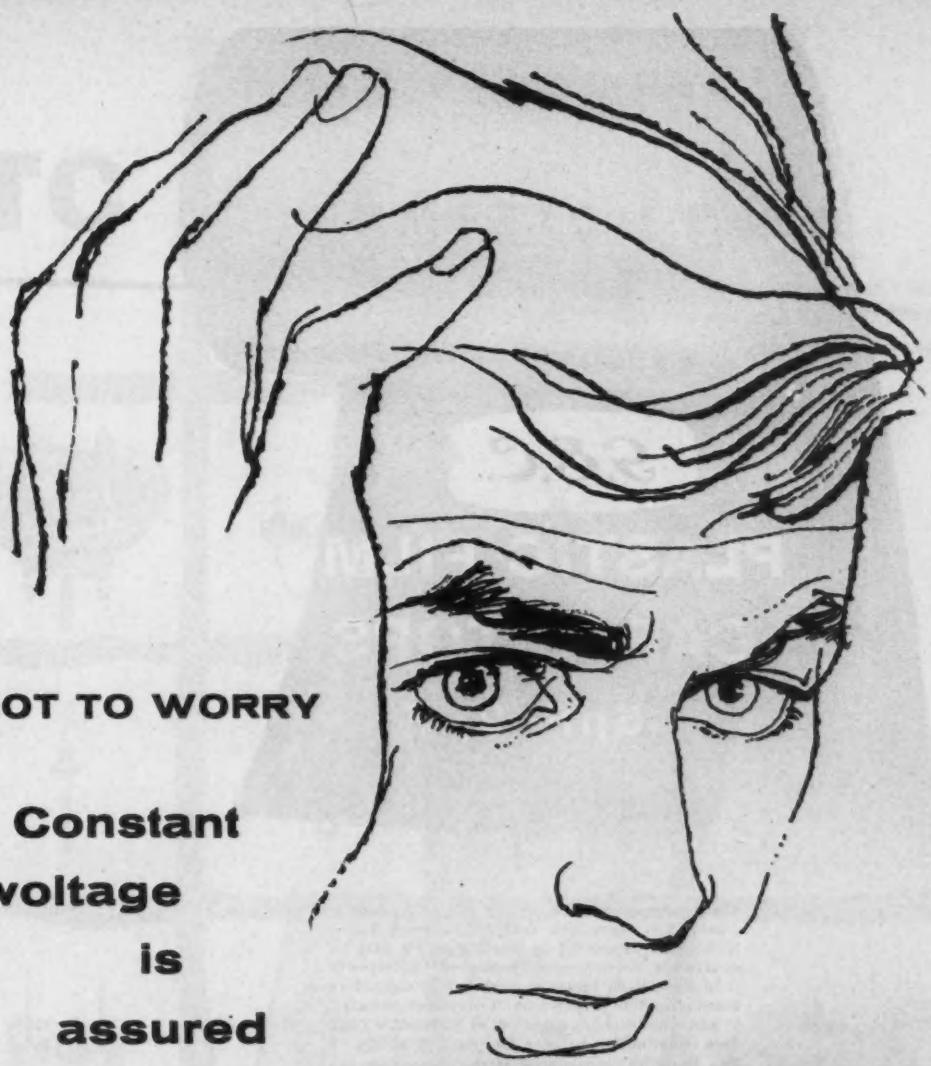

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Constant voltage is assured

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A VOLSTAT is the answer to many a.c. voltage fluctuation problems. In most cases, a standard type is all that is required—but there are occasions when a special design may be necessary. Either way an 'Advance' Technical Representative will be pleased to investigate your own particular problems, and recommend a VOLSTAT best suited to your needs.
VOLSTAT stands for a complete range of Constant Voltage Transformers produced by 'Advance'—the leading authority on voltage stabilization.
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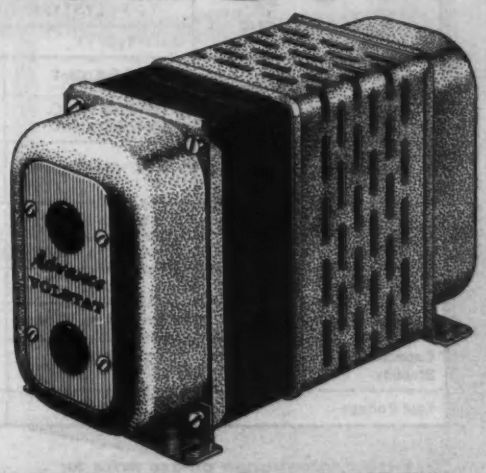

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5pF–2μF

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Overall Range	5pF–510,000pF	150pF–510,000pF	0·001μF–2μF	0·05μF–2μF
Working Voltages	125–2,000 V.D.C. 750–2,000 V.A.C.	125 V.D.C. 350 V.D.C. 750 V.D.C. 2,000 V.D.C.	150 V.D.C. 250 V.D.C. 350 V.D.C. 500 V D.C.	150 V.D.C.
Insulance or Insulation resistance	10^6M Ω	10^6M Ω	20,000M Ω /μF or 50,000M Ω whichever is the less	20,000M Ω /μF or 50,000M Ω whichever is the less
Working Temperature Range	−40°C to +70°C derate stability at +70°C to +85°C	−40°C to +70°C	−40°C to +100°C derate voltage at +85°C	−40°C to +100°C derate voltage at +85°C
Power Factor	≤·0005	≤·0005	≤·007	≤·007
Temperature Coefficient	120×10⁻⁶ per °C nom.	−130±15×10⁻⁶ per °C	+200×10⁻⁶ per °C nom.	+200×10⁻⁶ per °C nom.
Capacitance Stability Temperate	≈0·25%	≈0·05%	≈0·5%	<0·5%
Capacitance Stability Tropical	†	•	<5% after H2	5%*
Test Voltage	3× wkg.	3× wkg.	2× wkg.	2× wkg.

*Rated RCS11 H1 †Requires sealing for tropical conditions

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IN APPLICATIONS RANGING FROM TRANSISTORS TO REFRIGERATORS, STC HERMETIC SEALS HAVE PROVED THEIR PERFORMANCE AS HIGH GRADE COMPONENTS

From their wealth of experience and "know how" in so many fields, STC have evolved a range of seals to meet the most exacting standards of hermetic sealing. STC hermetic seals are available for many applications including:

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- Crystal base seals.
- Refrigerator seals.
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Write for publication MK/153 which gives details of these and other STC Hermetic Seals.

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61/8MK

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TRANSISTOR DIVISION: FOOTSCRAY · SIDCUP · KENT

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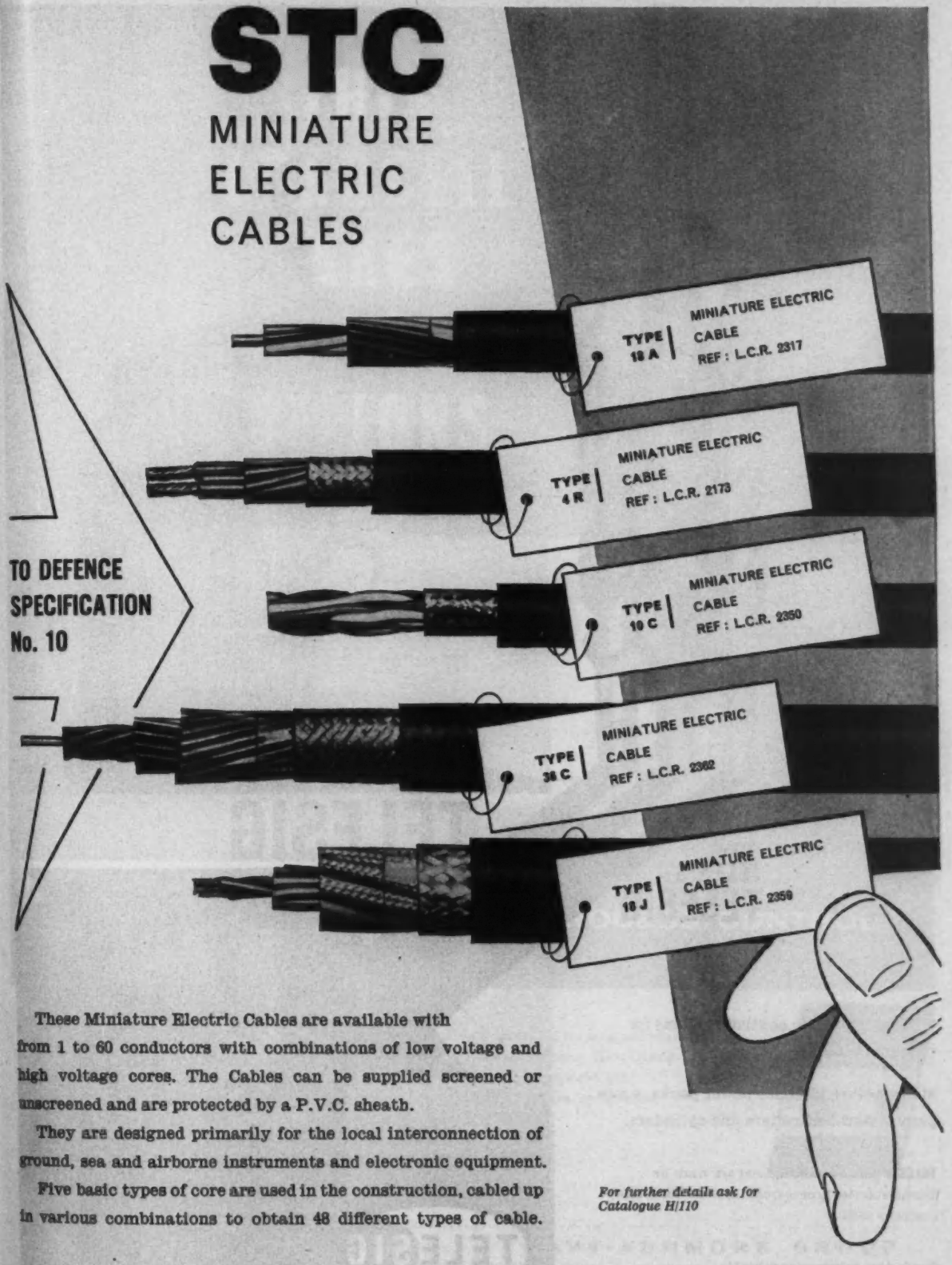
STC

MINIATURE ELECTRIC CABLES


TO DEFENCE SPECIFICATION No. 10
TYPE 18 A | MINIATURE ELECTRIC CABLE REF : L.C.R. 2317
TYPE 4 R | MINIATURE ELECTRIC CABLE REF : L.C.R. 2173
TYPE 10 C | MINIATURE ELECTRIC CABLE REF : L.C.R. 2350
TYPE 38 C | MINIATURE ELECTRIC CABLE REF : L.C.R. 2362
TYPE 18 J | MINIATURE ELECTRIC CABLE REF : L.C.R. 2359

These Miniature Electric Cables are available with from 1 to 60 conductors with combinations of low voltage and high voltage cores. The Cables can be supplied screened or unscreened and are protected by a P.V.C. sheath.

They are designed primarily for the local interconnection of ground, sea and airborne instruments and electronic equipment.

Five basic types of core are used in the construction, cabled up in various combinations to obtain 48 different types of cable.

For further details ask for Catalogue H/110

CABLE AND WIRE GROUP

61/3H

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RUBBER & PLASTIC CABLE DIVISION: CORPORATION ROAD · NEWPORT · MON.

Circle **No 26** on reply card for further details

Vertical electrode press operated by high pressure screw pump.

TELESIG

TELESIG

TELESIG

TELESIG

Telesig hydraulic control systems for machine tools.

Manufacture includes power packs, screw pumps, flow controllers and cylinders.

TELESIG pumps and equipment are made by Telehoist under licence from the Swiss Industrial Company (SIG).

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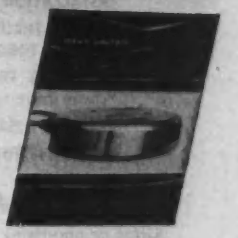

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The New 100 S.D. SERIES

Electrical Valve ACTUATORS

NO OTHER ACTUATOR *provides these* **STANDARD FEATURES:–**

- **WEATHERPROOF**
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  Unit does not run in oil bath
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  Power drive to Handwheel and vice versa
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- **HIGH EFFICIENCY SPUR GEARING**

ANY VALVE ANY SIZE ANY ANGLE

Rising or non-rising spindles · Stem Diameters up to 4¼"
Valve spindle torques from 60-3500 lb./ft. at 24 r.p.m.
Thrusts from 12,000 to 150,000 lbs.
Also available flameproof-weatherproof versions

Years ahead for years to come!—Send for full technical details

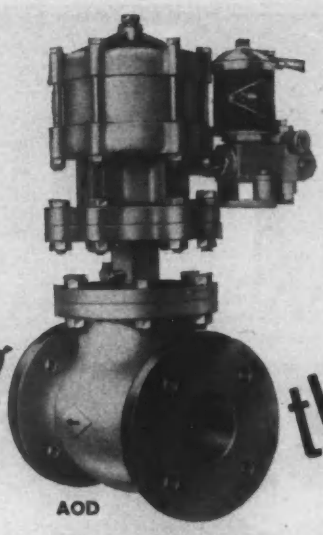
JONES TATE AND COMPANY LTD. (DIVISION OF DEWRANCE)

Great Dover Street, London, S.E.1 Tel. HOP 3100

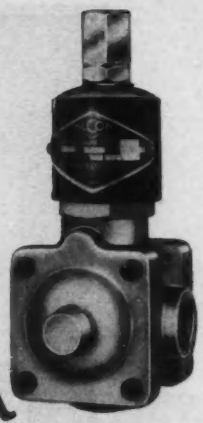
The AMPEX CP-100 is a compact, extended-frequency instrumentation tape recorder/reproducer. Tape transport, motor drive amplifier, heads, power converter, controls and all-transistorized plug-in record/reproduce electronics are contained in a single 13¼" x 19" x 33¼" mobile case. The CP-100 operates on 28-volt DC, with 48 to 400 cycle converters available for other power sources. Data is recorded by direct or FM carrier techniques on up to 14 analogue tracks. The CP-100 offers frequency response to 200 Kc at 60 ips or expanded recording time of 24 minutes for 100 Kc data at 30 ips on a standard 10½" reel. Transport tape speeds – 1⅞, 3¾, 7½, 15, 30 and 60 ips – and plug in frequency determining units and equalizers associated with tape speeds, may be quickly changed. The versatile and mobile CP-100 performs reliably over a temperature range of from –50° F to +160° F, up to an altitude of 10,000 feet, in relative humidities to 95%... and is designed to withstand shocks and vibrations encountered in rugged mobile testing applications. This recorder may also be rack mounted if desired. For complete details write Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

ACH

anything that flows



AOD



SPC 3

ACO

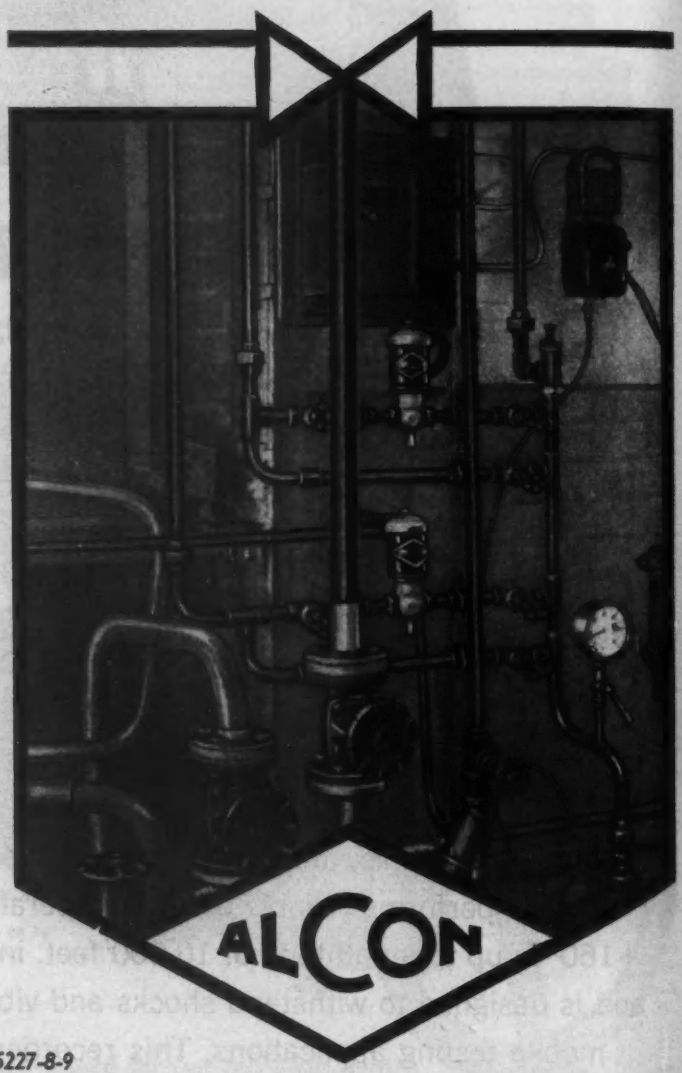
All Liquids and Gases can be positively controlled by an Alcon Solenoid or Air-Operated Valve. Sizes from ⅛" B.S.P. to 8" Bore. Pressures up to 1,500 p.s.i. Temperatures up to 300°C. Body materials to suit all media including corrosive acids, with Standard, Weatherproof or Buxton Certified Flameproof Solenoid Housings. Glandless, Fluon Glands or Stainless Steel Bellows Glands.

AIR-OPERATED Type AOD —Heavy duty air operated units individually designed for control applications beyond capabilities of Solenoid types. For pressures up to 1,500 p.s.i. Sizes ¼" B.S.P.—8" Bore.

SPC.3—Three-way valves for electro-pneumatic control systems. Sizes up to ½" B.S.P. for use with air up to 150 p.s.i.

MIDGET Type ACO—Sizes up to ½" B.S.P., used for control of air, gases, water, oil at pressures up to 300 p.s.i. Single way—Reverse acting—Three-way types available.

ACH—Hand Reset type, closing automatically on current failure, for low and medium pressures. Sizes from ¼" B.S.P. to 6" Bore. Inexpensive, simple construction, reliable in operation. Also available type ACHL. Lever operated for use with steam, hot water and pre-heated fuel oils.



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A MEMBER OF THE CONCENTRIC GROUP OF COMPANIES

If you want a small relay capable of switching fairly large loads you should know all about the new B & R B11/2.

Here is a summary of information:

* **Fitted with one (normally open) heavy duty contact**
* **Max. rating: 10 amps at 240V A.C.**
  20 amps at 30V D.C. non-inductive
* **Weighs only 2¼ ounces**
* **Coils can be vacuum impregnated (to meet general M.O.D. spec. Def. 5000)**

Further details of this relay which can be modified to meet individual requirements, are available from

B&R RELAYS LIMITED

B & R RELAYS LIMITED · TEMPLE FIELDS · HARLOW · ESSEX

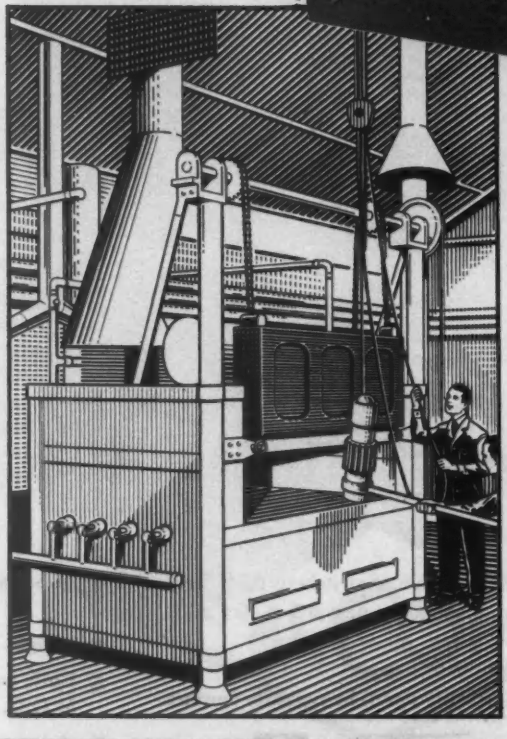
Telephone: Harlow 25231 *Member of the Gas Purification Group*

Automatic Ignition

safeguards flame failure

These high-quality controllers eliminate the dangers arising from flame-failure, and are effective in almost all types of gas-fired and oil-fired furnaces. They employ an infra-red sensitive photo-cell to 'see' the flame in furnaces, which discriminates between flame and furnace-radiation. The photo-cell reacts instantly to flame-failure and, should this occur, the fuel supply is immediately shut off by an electronic control unit.

Other controllers operating on flame-conductivity or flame-rectification, and complete installations, are also available.



Above is the ETHER Control Cubicle Type 704, fully transistorised, for monitoring up to six burners. The relays are all interlocked to give fully automatic ignition control.

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Full details gladly forwarded on request:
ETHER LTD., Combustion Safeguards Division,
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Stevenage 2110-7

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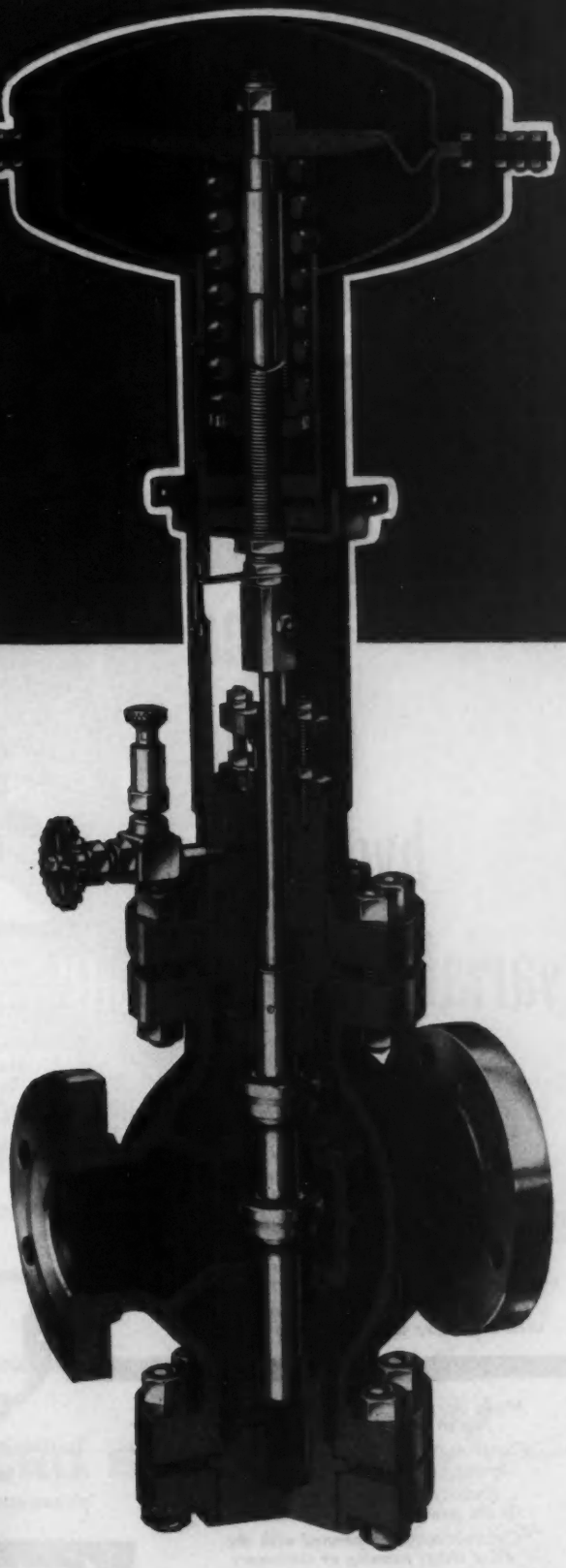
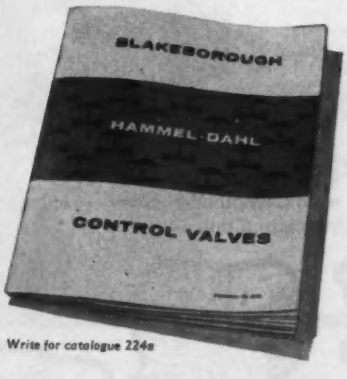
DIAPHRAGM CONTROL VALVES



Accurate, reliable, and economical these Blakeborough types do full justice to the performance of the controlling instrument—hence their widespread use on modern automatic process control systems. An advanced and comprehensive range, well worth investigating.



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BLAKEBOROUGH

J. BLAKEBOROUGH & SONS LTD · BRIGHOUSE · ENGLAND

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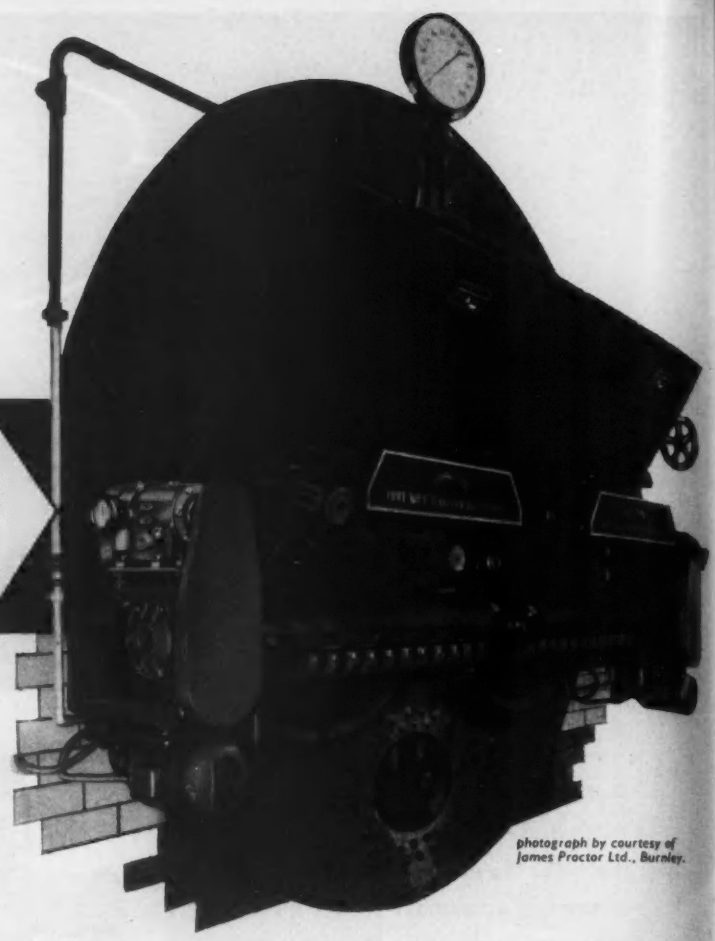
This Compact Unit is the Carter hydraulic variable speed gear . . . .



photograph by courtesy of James Proctor Ltd., Burnley.

. . . . . chosen by James Proctor Ltd., Burnley, for their Unit Wide Ram Coking Stoker illustrated above.

Wide infinitely variable speed range (approximately 27/1 on full load).

Sensitive accurate speed control by Hand, Electrical or Lever arrangements.

Constant output torque throughout the entire variable speed range.

Positive displacement action ensures maximum 'controllability' at all speeds.

Carter Variable Speed Gears may be used to pick up loads from zero r.p.m.

The Size F 10 Carter Gear fitted with Combined Handwheel and Speed Indicator Control.

Made in eleven sizes for fractional up to forty horsepower drives.

Flange mounted reduction gears can be supplied for slow speed drives.

Entirely self-lubricating since oil is the power transmitting medium.

Controls may be operated with the drive either running or stationary.

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The New BURGESS V-4

* No larger than the average cuff-link
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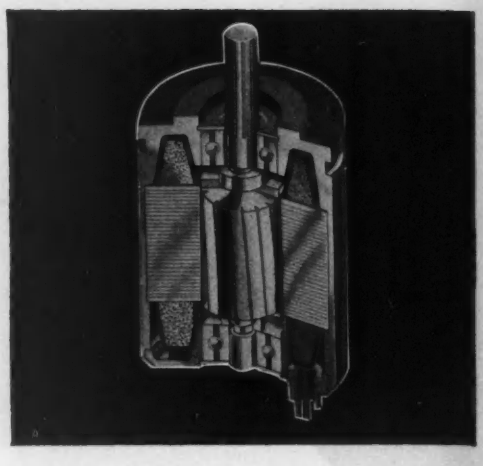

Combining precision engineering with rapid response and stability of performance over a wide temperature range, Ketay Size 08 Synchros and Servomotors have been developed as part of a continuous programme to provide miniature components of improved performance and environmental resistance. Both Synchros and Servomotors have encapsulated stators, nickel alloy laminations and hermetically sealed windings which make the units essentially corrosion resistant.

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- High accuracy: less than ± 7 minutes of arc error
- Temperature range: minus 55°C to plus 77°C (special version for 150°C will be available)
- Light weight: only 1.5 ounces (43 grams)
- High torque gradient: pre-loaded stainless steel bearings
- Stainless steel housings: through-bore construction

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- Outstanding high ratio of stall torque to power input (0.22 oz. in. for 1.75 watts control phase)
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Ketay

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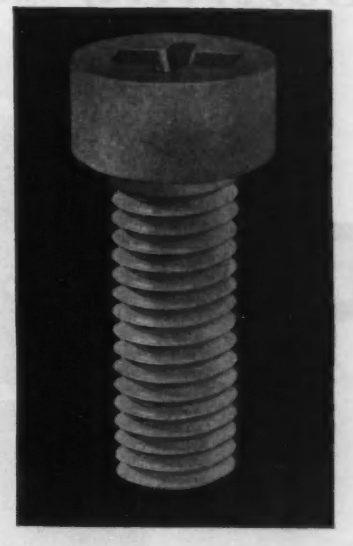
not to keep telling them
about GKN
NYLON SCREWS.



Yes, yes, their insulation
and dielectric
strengths are high;
and they can stand
sterilising
again and again;
and their
tensile strength
is 3500 lbs./sq. in
but on top of this
these chemically inert,
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vibration proof,
six to seven times
lighter-than-steel
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GKN Nylon Screws

are made with either SLOTTED or PHILLIPS RECESS heads.

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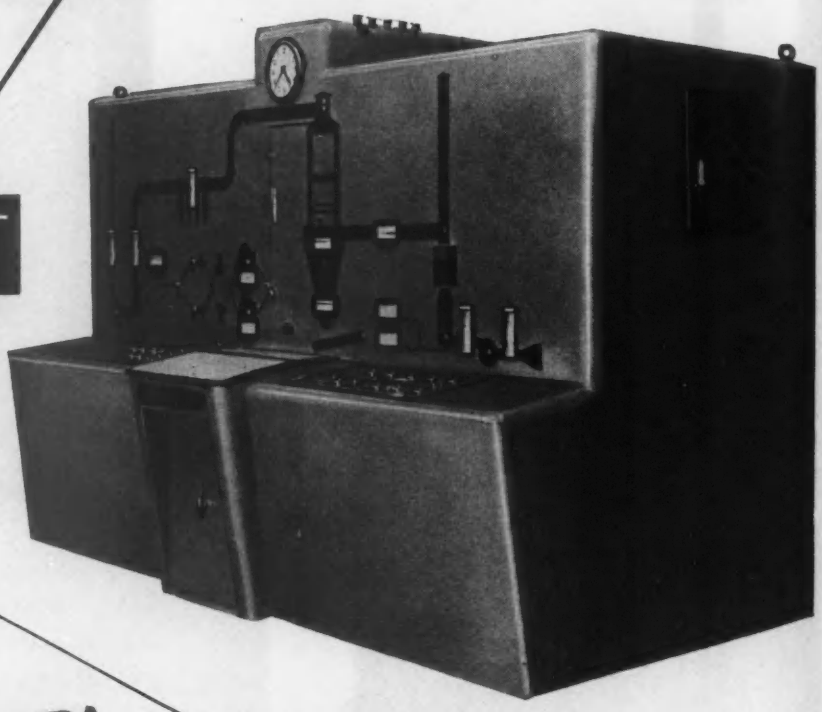
Built to the design and specification of PEABODY LTD



CONTROL desks and panels

Lintott offer a complete service for the fabrication, finishing *and* electrical assembly of all forms of control gear in the electronics and nuclear energy fields. Lintott constructions are in use for a wide variety of process controlling, fuel control, burner control, etc. They can be finished for interior or exterior use, pressurized, and in desk, panel or cubicle form.

LIN-CABINET chassis racks

A specialised Lintott construction providing a completely flexible system for housing electronic and electro-mechanical equipment. Each unit is self-contained, with built-in cooling or heating facilities, and are suitable for slight pressurization. Standard drawers of 8", 12" and 16" depth can be used in any combination to give a total height of 52". Lin-cabinets are K114 approved for the three Services. Write for full details.

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AYLING INDUSTRIES GROUP

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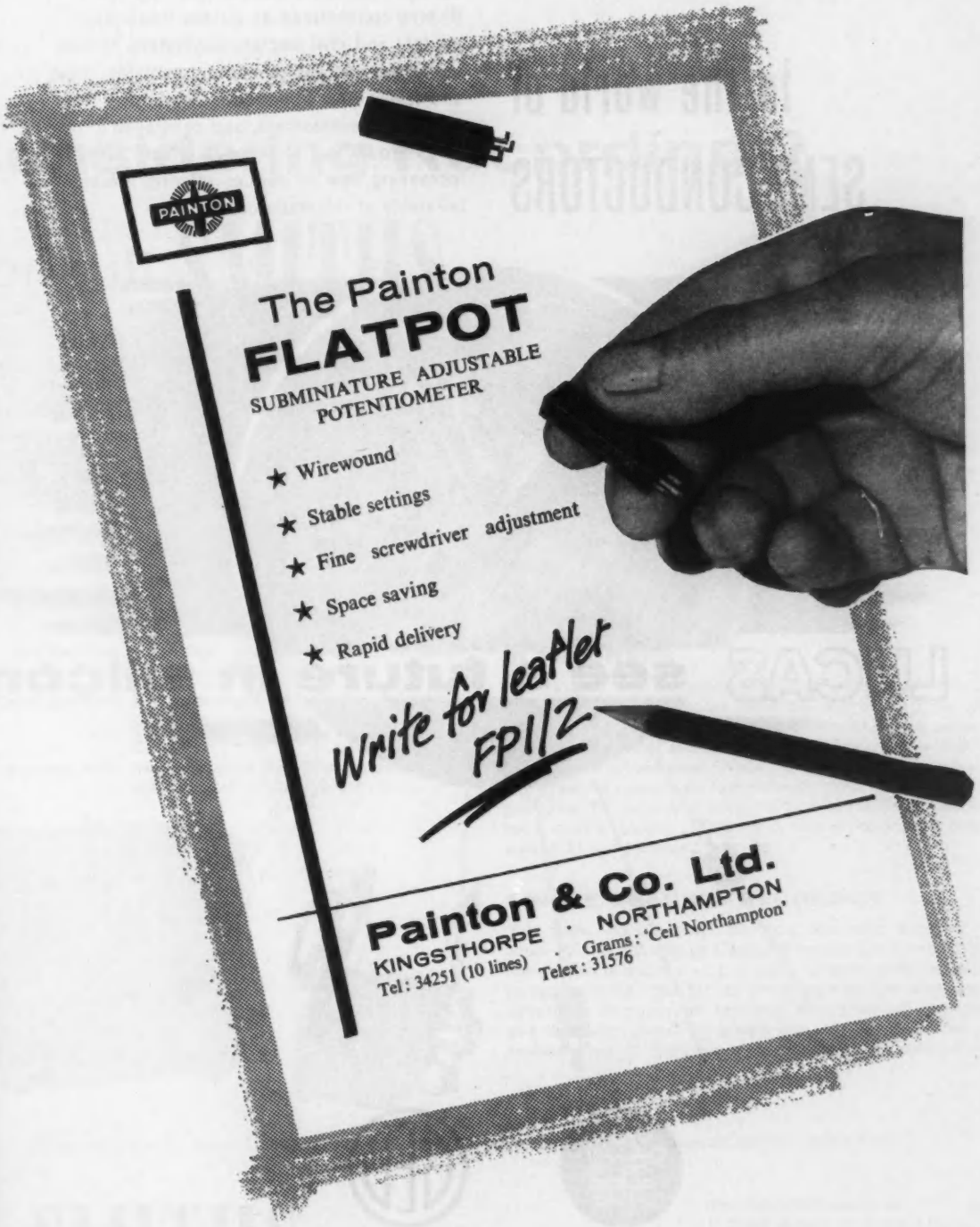

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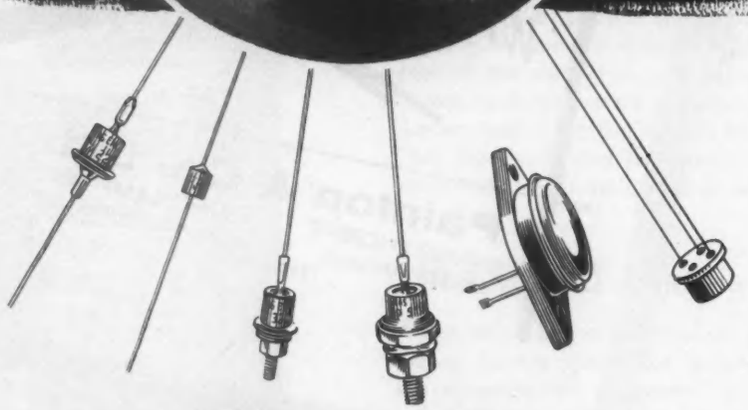
In the world of SEMI-CONDUCTORS

A wide range of high quality power transistors, voltage regulators and rectifiers for such diverse applications as guided weapons, military and civil aircraft, computers, railway modernisation equipment, automobiles, radio and television. Continuous research, extensive development, and controlled mass-production techniques ensure an ever-increasing flow of devices offering maximum reliability at minimum cost.

LUCAS see a future in silicon



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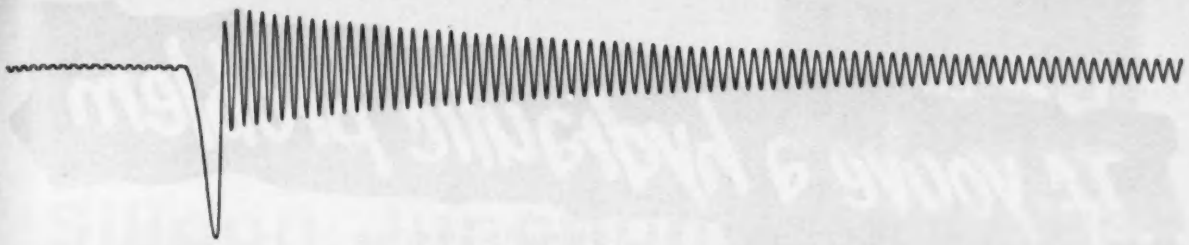


Considering Recording ?

consult SMITHS

SMITHS are specialists in high speed recording techniques and offer a wide range of instruments for instantaneous and permanent recording of many variables. These ruggedly built instruments are insensitive to external vibrations, and their rapid response, versatility, and dependability make them well suited for most research applications.

Variables Strain, displacement, acceleration, vibration, torsional vibration, speed, temperature, time, force and load, gaseous and liquid pressures, flow, etc.

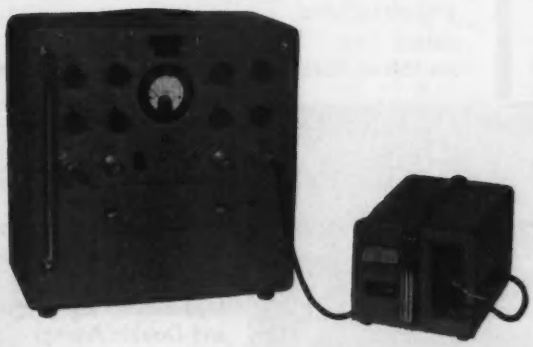
Recording Frequencies From d.c. up to 5,000 c/s.

Channels 1—14 in a single instrument.

D.C. Amplifiers For voltage, current, speed and temperature applications.

Carrier Amplifiers For recording from resistive, inductive, capacitive and differential transformer devices.

Recording Media Electro-sensitive, Heat Sensitive and Photographic instant print-out paper.



ULTRAGRAPH

This recorder can simultaneously record from 1—14 different phenomena having frequencies within the range of d.c. up to 5,000 c/s, when used in conjunction with multi-channel pick-up arrangements. It will provide instantaneous high definition recordings on 6 ins. wide sensitised paper. Mirror galvanometers deflect beams of high intensity ultra-violet light across the paper which requires no processing. The paper drive can be varied from 1 to 800 mm sec. and has a reading accuracy of 2%. An in-built device provides timing lines at 0.1 and 1.0 second intervals.

SINGLE CHANNEL RECORDER

This single channel strain recording equipment comprises an Amplifier Unit and a Single Channel Recorder. The Amplifier Unit incorporates a bridge circuit, 2 Kc/s oscillator, carrier amplifier, demodulator, d.c. amplifier and power supplies. The equipment is suitable for operation with resistance, inductance and capacitance pick-up devices. Sensitivity is such that a 1½ cms. deflection can be traced for a .005% change of resistance in a 2,000 ohms pick-up.

Please write for Technical Literature. Smiths specialists are freely available to advise on specific applications.

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The industrial business of S. Smith & Sons (England) Ltd. including the marketing of industrial products under the trade marks of Smiths and Kelvin Hughes.

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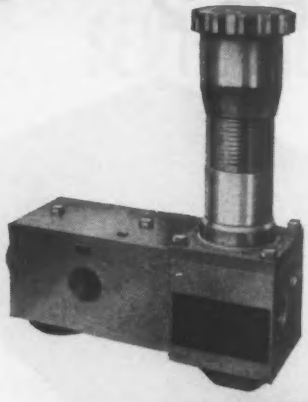
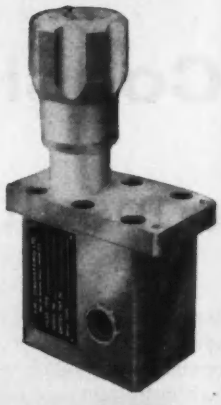
S/KH103

If you've a hydraulic problem



Experienced engineers at H.M.L. are always ready to get to grips with problems arising from the design requirements of modern hydraulic systems. You'll find H.M.L. Ministry approved units and components used and relied upon wherever high standards of performance are recognised.



HML VARIABLE PRESSURE REDUCER VALVE

The only pressure reducing valve on the market today that will maintain set reduced pressure under varying pressure and flow conditions. Pressure range 0-5000 p.s.i. Flow range 0-10 g.p.m.

... bring it to HML

HML EQUIPMENT INCLUDES:

- Pulsometer Pump Test Unit
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- Hydraulic Propeller Test Benches
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- Universal Hydraulic Tyre Remover
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- Valves
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- High-speed Gear Boxes
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- Hydrostatic Rig (Single and Double Acting)
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All types of special hydraulic test equipment built to users' own requirements. The unit shown was supplied to a large aircraft company

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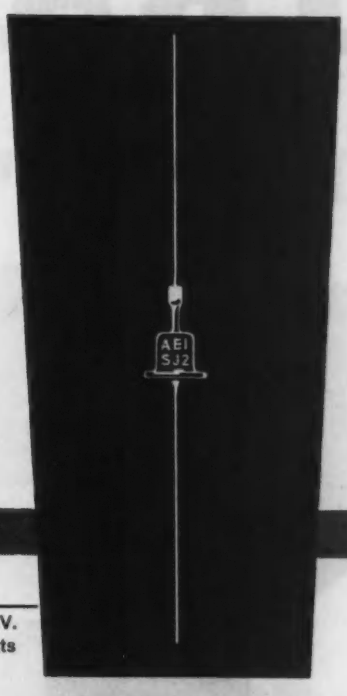
Silicon Junction Rectifiers

Now with these new

Improved design features

Special protective, non-conductive silicone-enamelled finish over silver plating. Minimizes the possibility of flash-over in dirty environments. (Cooling fin efficiency is unaffected.)

Reduced flange diameter. Wire-ended Form 'F' units 0.4 in. max. Saves space in electronic equipment.



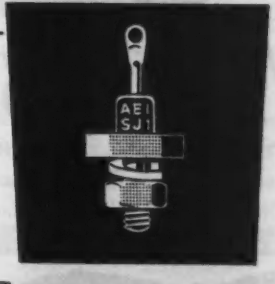
Type SJ Rectifiers are:

RESISTANT TO SHOCK AND VIBRATION
COMPLETELY RELIABLE · FULLY 'TROPICALISED'

Ratings

TYPE	P.I.V. Volts	TYPE	P.I.V. Volts	TYPE	P.I.V. Volts	TYPE	P.I.V. Volts
MAXIMUM CURRENT AT 25°C							
0.7 amp.		1.0 amp.		1.5 amp.*		2.3 amp.*	
SJ051F	50	SJ052F	50	SJ051A	50	SJ052A	50
SJ101F	100	SJ102F	100	SJ101A	100	SJ102A	100
SJ201F	200	SJ202F	200	SJ201A	200	SJ202A	200
SJ301F	300	SJ302F	300	SJ301A	300	SJ302A	300
SJ401F	400	SJ402F	400	SJ401A	400	SJ402A	400
SJ501F	500			SJ501A	500		
SJ601F	600			SJ601A	600		
MAXIMUM JUNCTION TEMPERATURE							
120°C		200°C		120°C		200°C	

* When mounted on suitable cooling fin



APPLICATIONS
• Rectification • Control
• Magnetic amplifiers
• Brushless alternators
• Power packs • Blocking duties

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Temperature Controllers

...have already proved their reliability and durability to thousands of firms in all industries!

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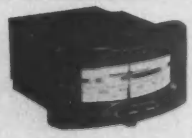
Two-position on/off.

Operating:
Solenoid valves.
Motorised valves.
Contactors. Relays.
Electric heaters.

Applications:
Salt-baths for heat-treatment of metals.
Vitreous-enamelling furnaces.
Muffle furnaces.
Hot-air ovens.
Drying kilns.
Crucible furnaces.
High-temperature alarms.
Extruding and moulding machines, etc., etc.



TYPE 991:
Anticipatory

Operating:
Solenoid valves.
Motorised valves.
Contactors. Relays.
Electric Heaters.

Applications:
Extruding machines and moulding presses for plastics, rubber, etc.

Die-casting machines.

Furnaces for crystal growing.

Chemical processing.
Food packaging machinery, etc., etc.

TYPE 992:
Proportioning
(stepless)

Operating:
Saturable reactors.

Applications:
Electrically-heated equipment requiring extremely accurate temperatures, e.g. plastic extruders for high-quality production.

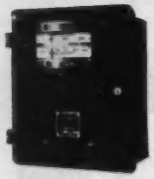
Electric furnaces employed on research.

Electronic production, etc., etc.

TYPE 993:
Three-position
(employing any combination of the preceding control systems).

Operating:
Solenoid valves.
Motorised valves.
Contactors. Relays.
Electric heaters.
Saturable reactors.

Applications:
For the independent control of sequential heating and cooling or for controlling a floating valve in:—
Salt-baths for heat-treatment of metals.
Vitreous-enamelling furnaces.
Muffle furnaces.
Crucible furnaces.
Extruding machines.
Moulding presses.
Die-casting machines, etc., etc.



TYPE 995:
Continuously-acting Proportional
(with manual reset)

Operating:
Motorised proportioning valves.

Applications:
Gas-fired or oil-fired molten-metal vats.

Continuously-fed furnaces.

Lehrs.

Drying ovens and kilns, etc., etc.

TYPE 994:
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(employing any one of the preceding control systems).

Operating:
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Motorised valves.
Motorised proportioning valves.
Contactors. Relays.
Electric heaters.
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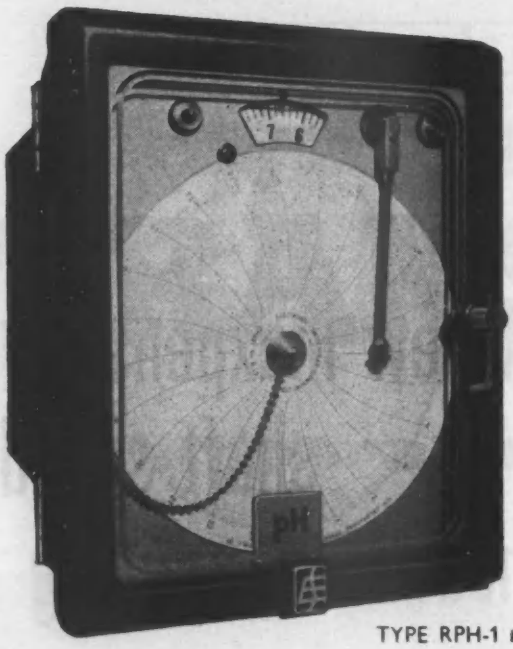

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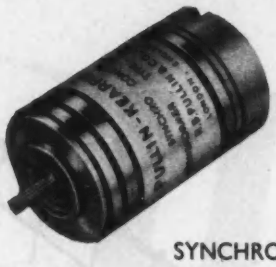

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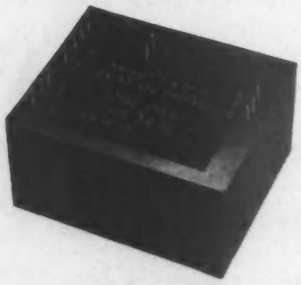

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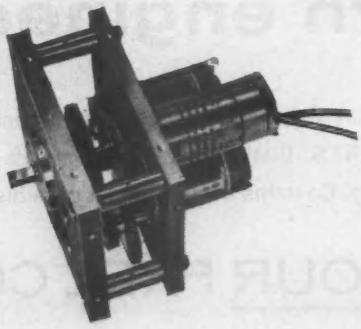

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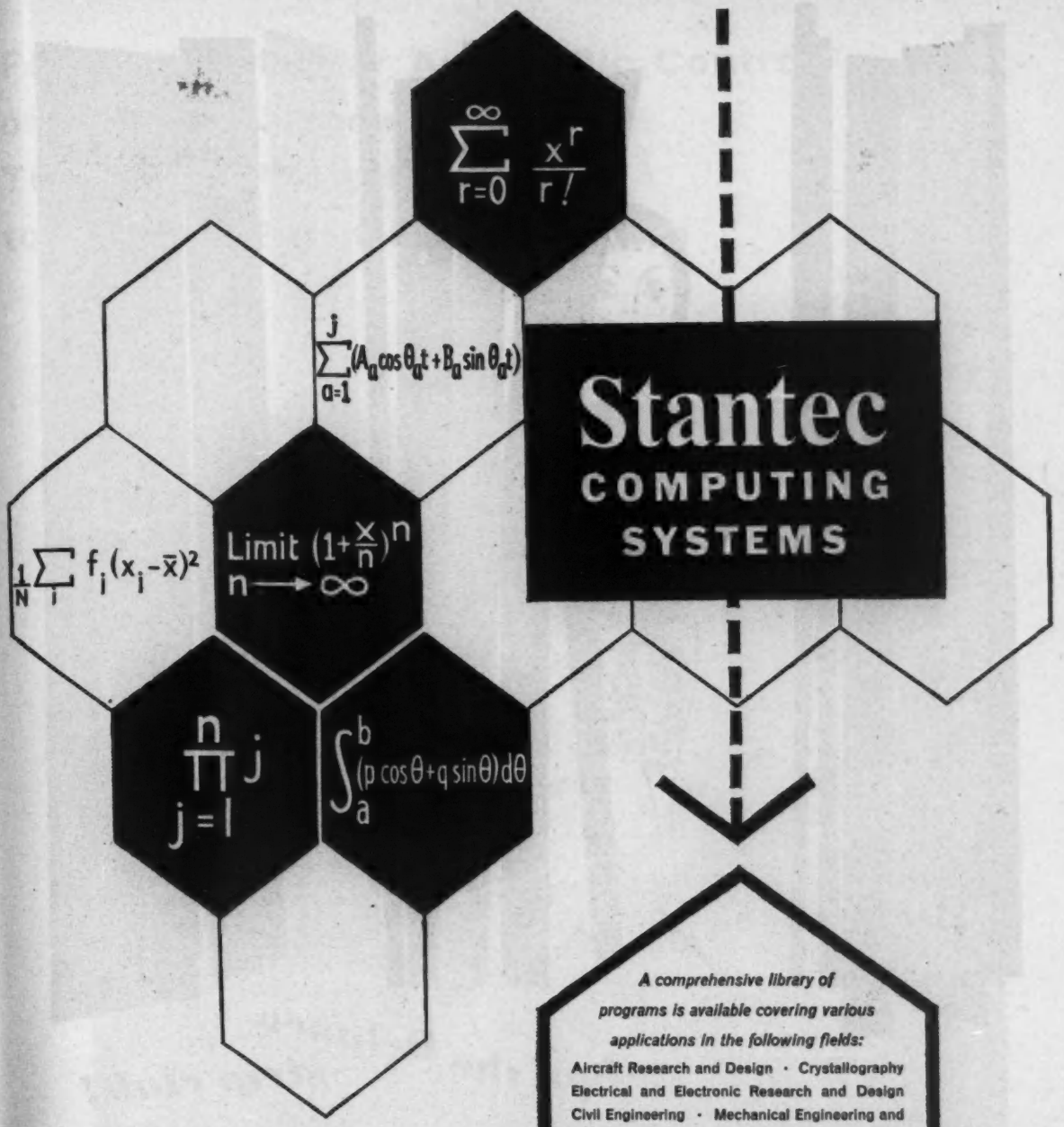

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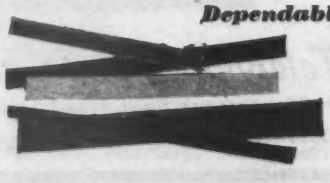

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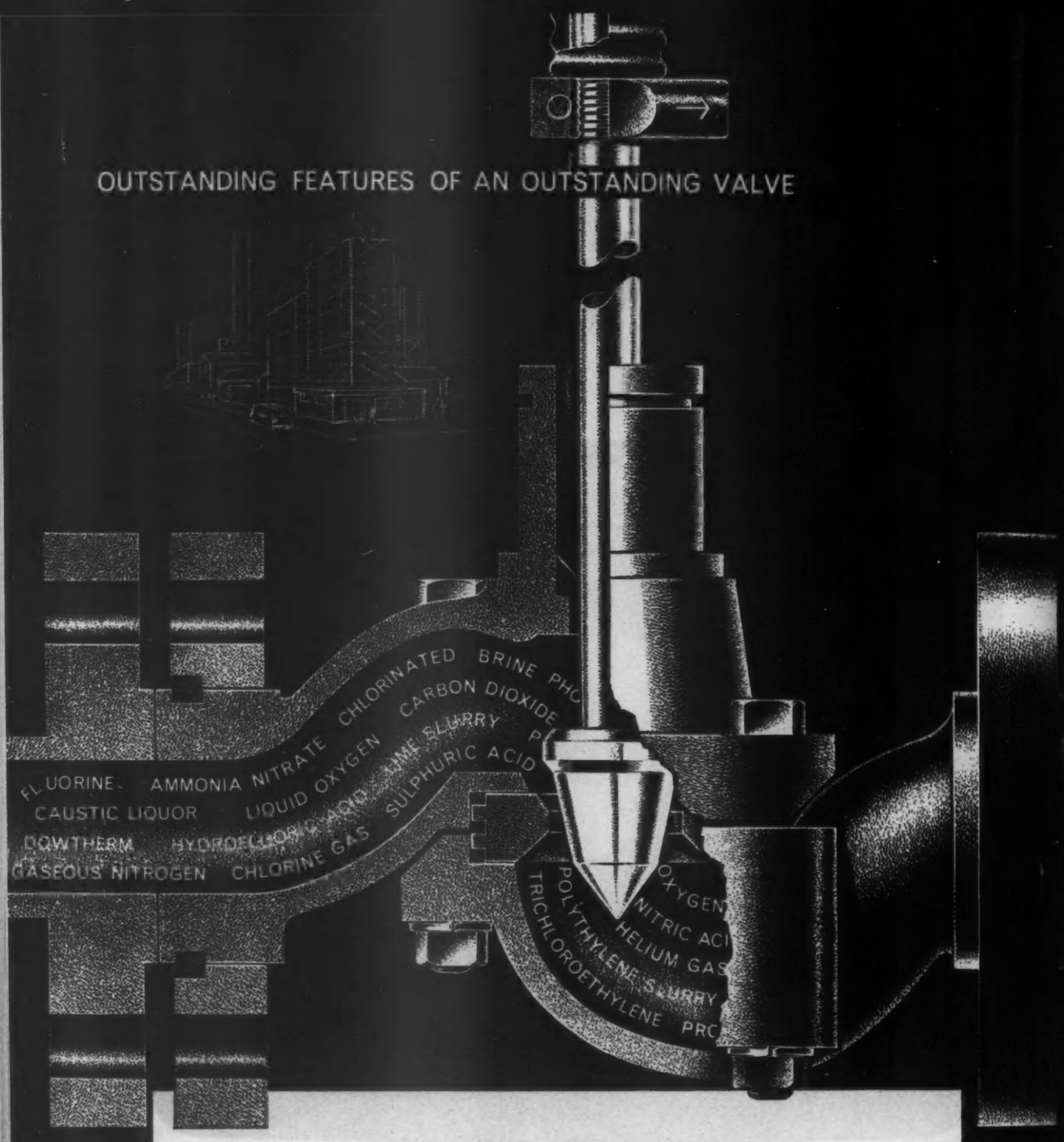

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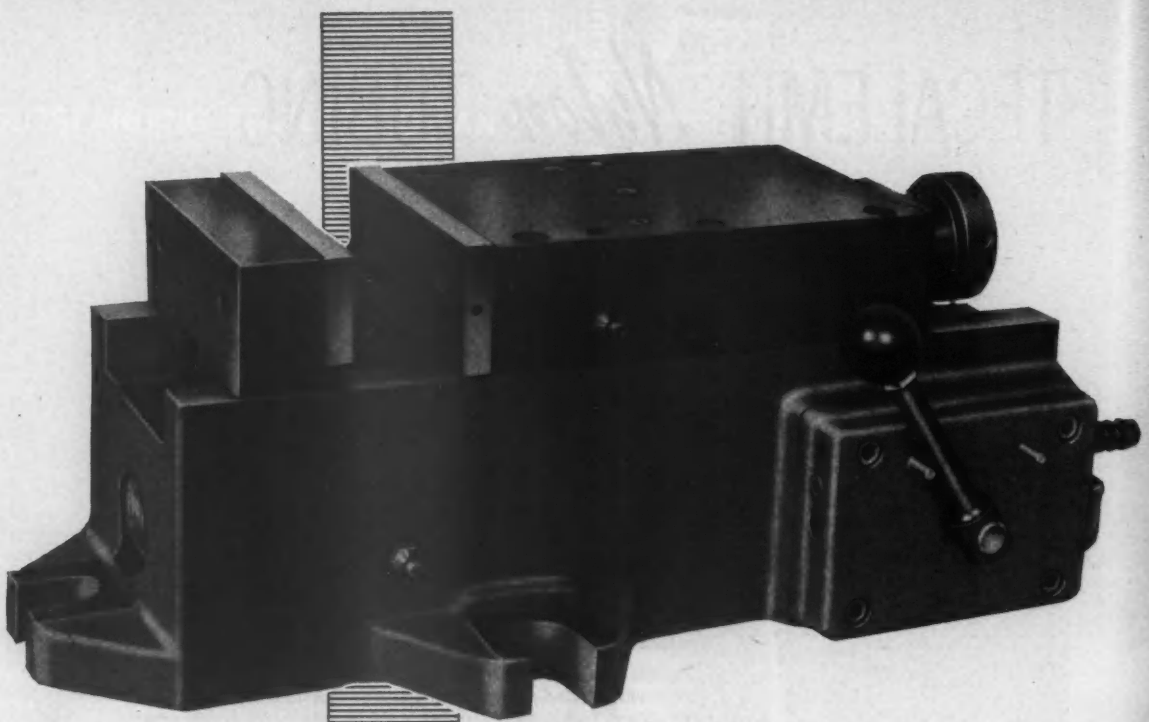

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Power Movement	⅛"	⅛"
Gripping Force at 80 P.S.I.	4,800 lbs	7,700 lbs
Length Overall	15½"	19½"
Width Overall	7½"	9½"
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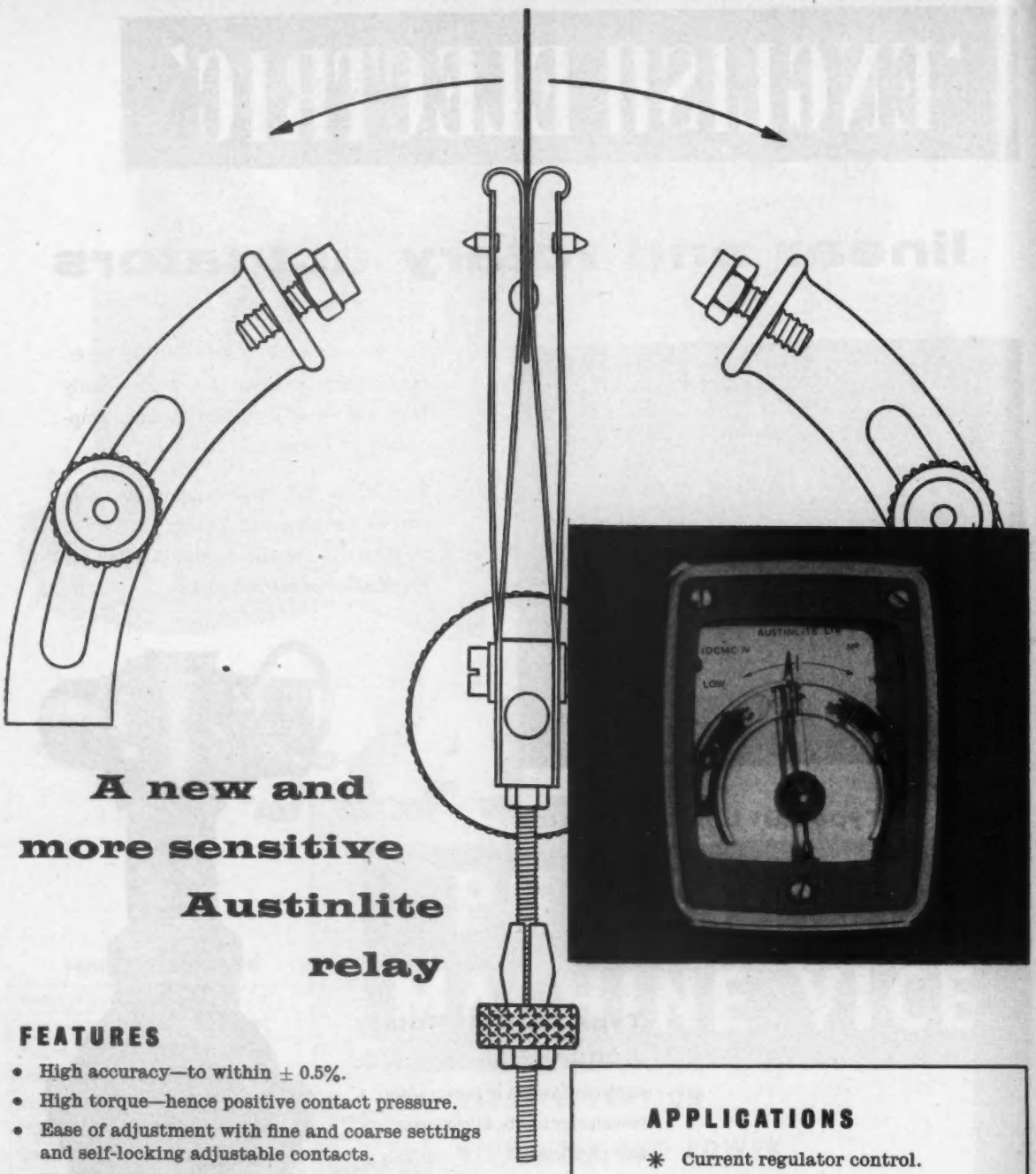

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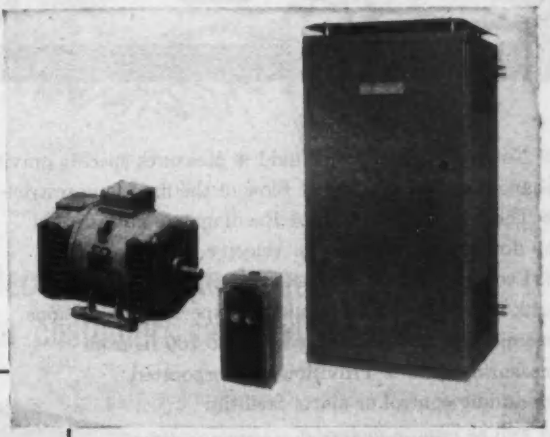

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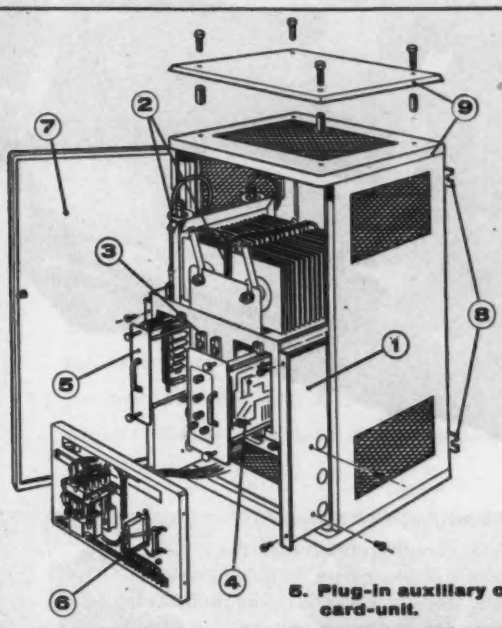

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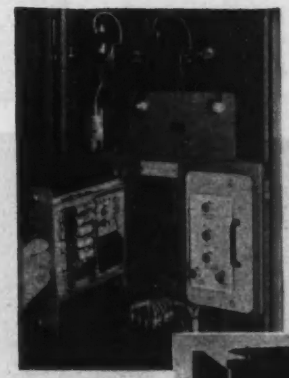

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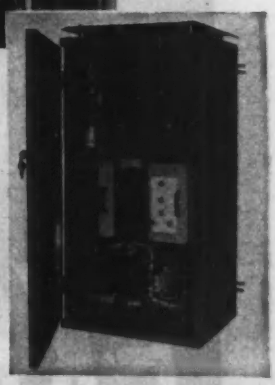

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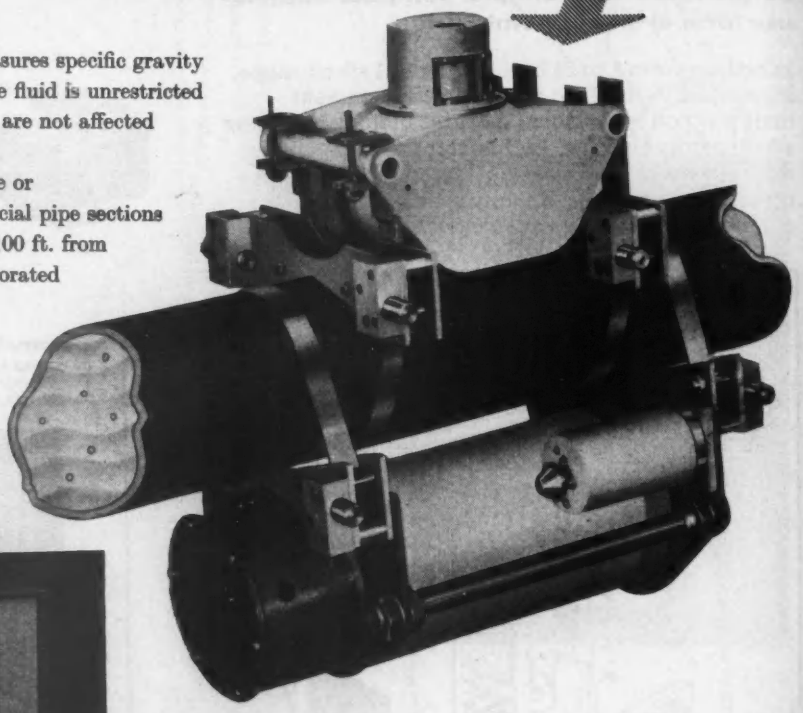

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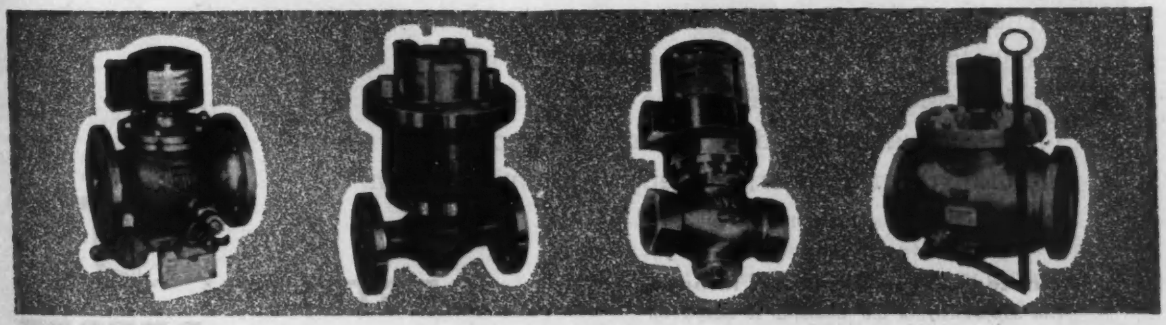

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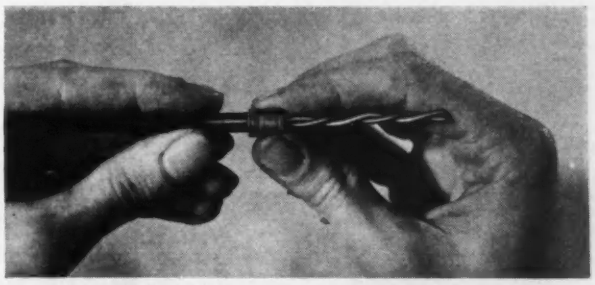
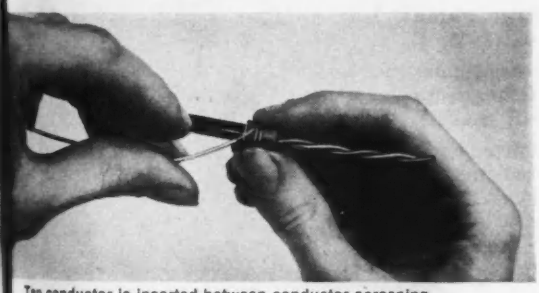


Uniring is fitted with inner sleeve sliding under the conductor screening, and over the insulation.



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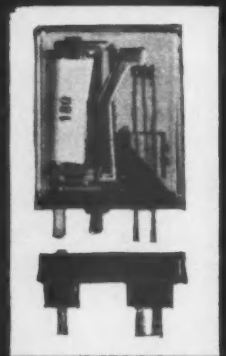
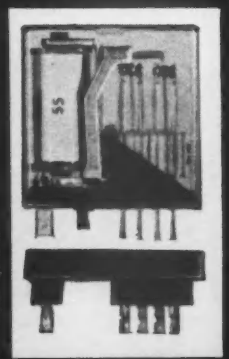


VP 4



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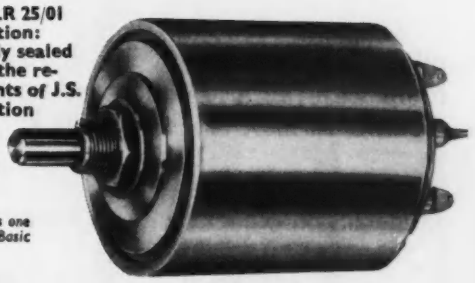

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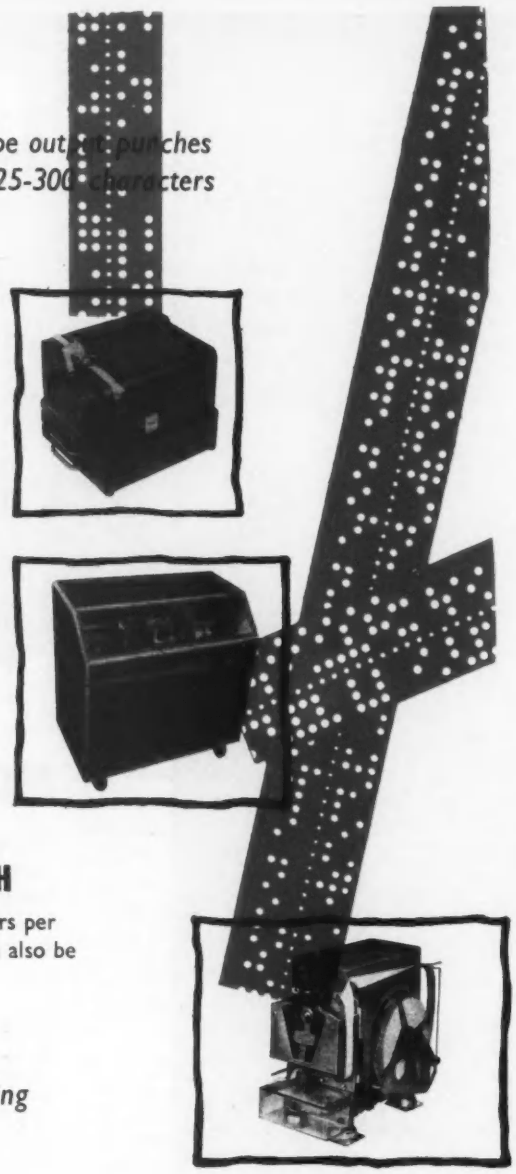

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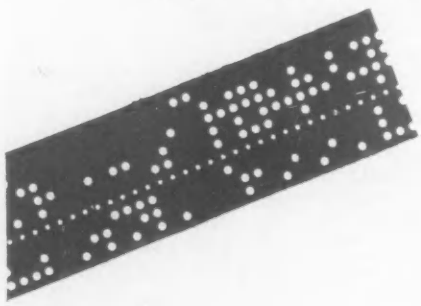

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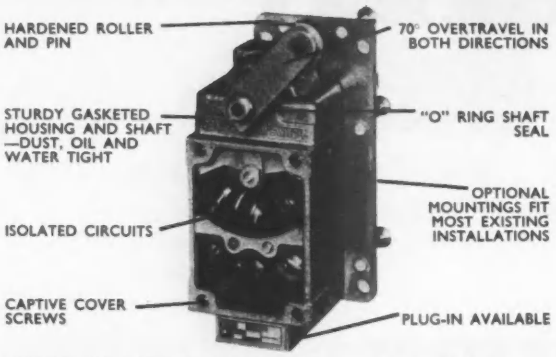
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500	7.5		15
600	6	.4	12

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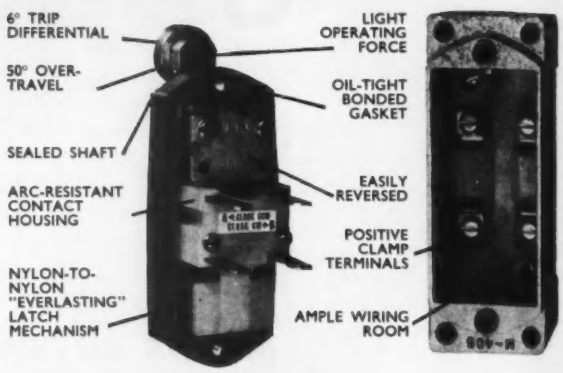

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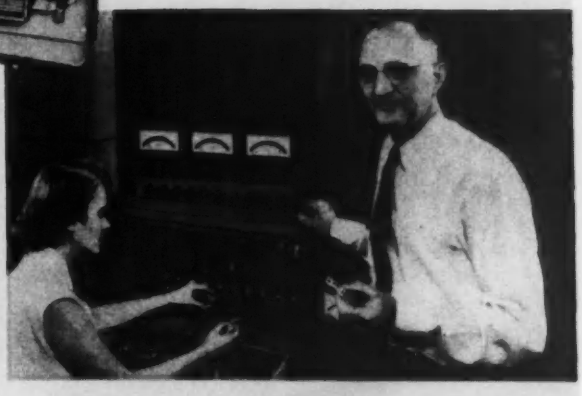

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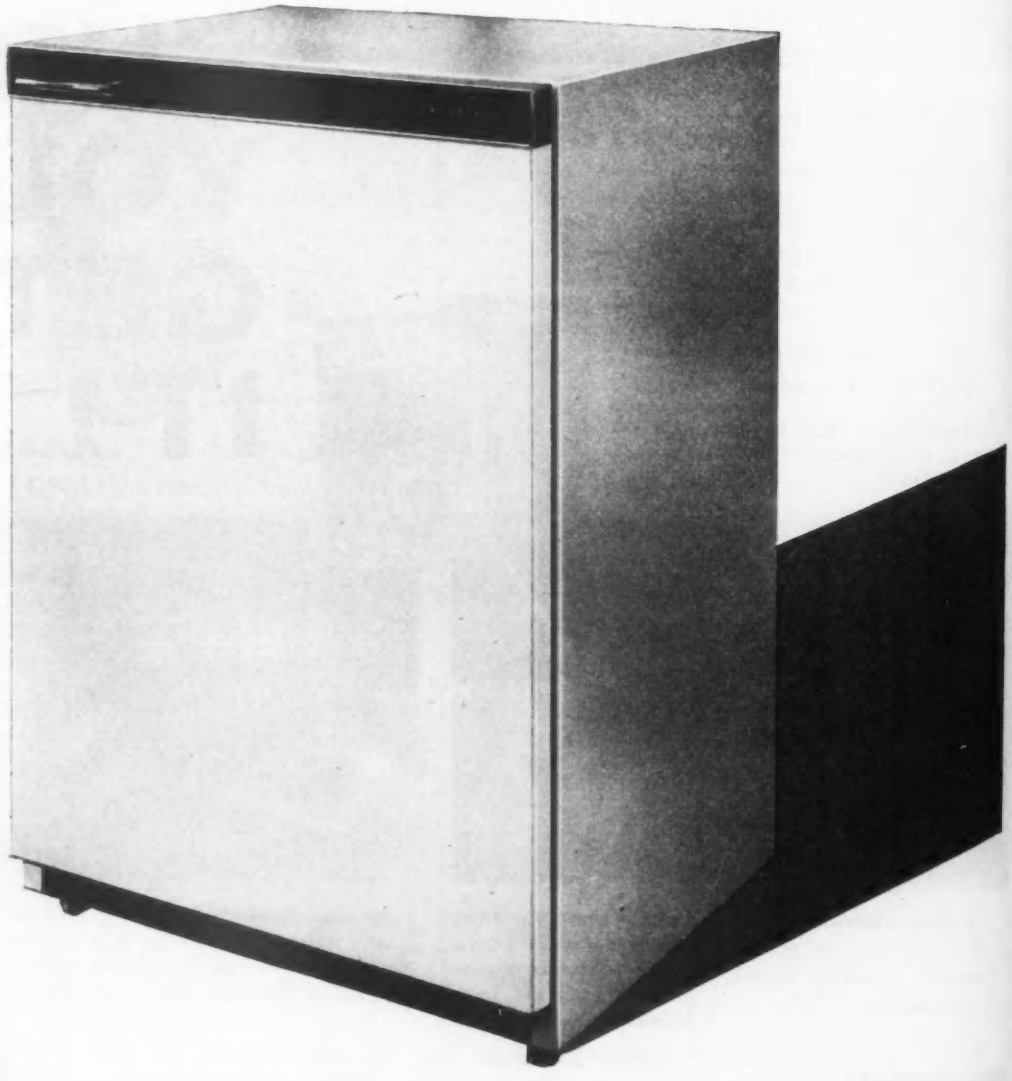

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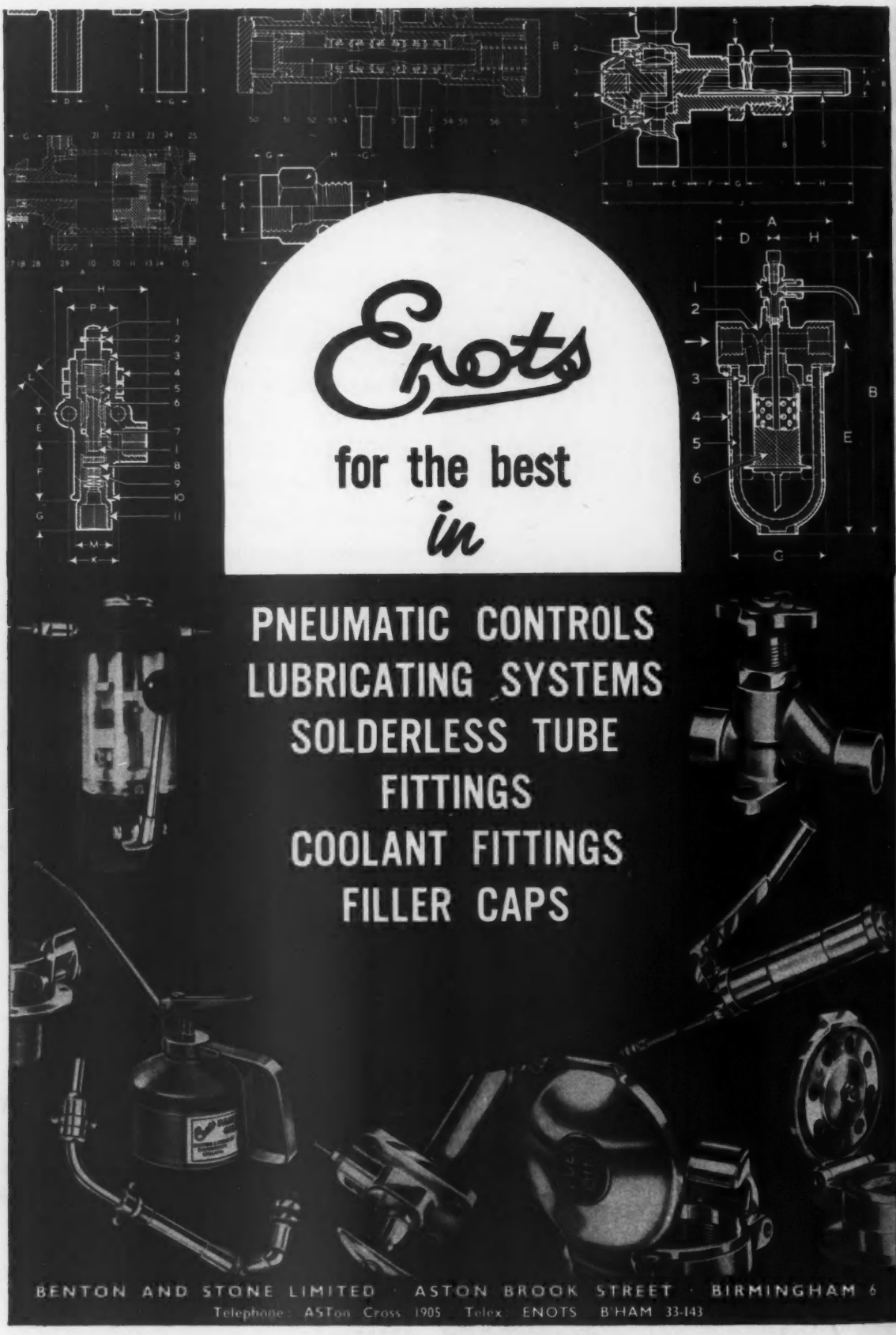

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JUNE 1961 VOL. 4 No. 36 CONTROL

Men, money, and automation

THE MANAGERIAL REVOLUTION has stimulated much new thinking on the functions of authority, but it is surprising how often the new notions turn out to be very ancient precepts wearing a contemporary hat. This does not make the precepts less valuable or less valid. Like re-translation of the Bible, modern interpretive discussion of leadership can make knowledge accessible to a larger number of people. This must be useful, because more managers are needed in industry. Unfortunately the eternal truths about men and the way in which they work together are necessarily discussed in very general terms, so it is only too easy for the philosopher to engulf all the details in a sea of principle and leave the practical man floundering.

The question of purpose is typical of the class of problem that seems simple at first and becomes a metaphysical muddle later. If a craftsman wishes to make an instrument (say), he can state his intention clearly and plan his work with great exactness—to him 'purpose' is what he intends to do, and there is nothing mysterious about it. Philosophically, however, purpose is as tough to deal with as causality: trying to analyse that, one traces a line of circumstances in which one seems to choose, more or less arbitrarily, a first point to label CAUSE and a second to label EFFECT. An analogous difficulty about purpose is bothering the people who have turned their intellects to management. According to Peter Drucker* the real purpose of a business 'must be outside of the business itself . . . in society', and it is 'to create a customer'. That is one view. But it is possible to regard commerce and industry as a host of intertwined lines of activity. If one then looks at any fairly distinguishable network among these lines—a particular company, and chooses a point on it—the creation of a customer, one may well ask whether this point can fairly be called the 'purpose' of the network. Looking at another point in the wriggling pattern—the profit—one asks: is it any more valid to say that this is the purpose of the activity?

To question the profit motive at the present moment may sound like heresy, if not worse, but it is worth while. The making of a profit must always be as much a part of business as making goods or providing a service, of course, but is it one end of a finite line? In the words of Roger Falk,* 'the "profit motive" no longer dominates business thinking', and 'if a detailed study were to be made of all the factors that go to the birth of a business, the "creative" one would probably emerge every bit as strongly as the more obvious desire to make a profit'. This is a profound truth, but the man who wants to seem hard-headed will find it very difficult to acknowledge.

The accountant's fallacy is that the sole purpose of enterprise is the avowed one of profit. It is an easy fallacy to fall into. Economic criteria are fairly easy to formulate, and monetary measures of performance come so readily to hand that they may be mistaken for best and most comprehensive measures. Clearly they must always be very important factors, but there are also many other considerations, especially in an age when industry has wrought great changes in the pattern of society and the apparent purposes of people. The promise held out by full automation is of still greater change along these lines, and this promise raises probably the most vital problems facing management today.

Although too many sectors of British industry are lagging in automation at present, eventually they are all bound to get involved in modern technological progress and its consequences. At the end of this month the B.C.A.C. is to run at Harrogate what it calls 'the first British conference on the social and economic effects of automation', and Lord Hailsham is to open the meeting.† This gathering may mark an intelligent re-awakening of public interest in at least some features of automation, and it may also presage a few stirrings in Governmental circles. We fear that the 'effects' to be discussed at Harrogate will, for this country, be mostly predicted ones, because there has not yet been enough automation here for them to be very much more: but a concerted attempt to foresee now will perhaps expose the lack of foresight hitherto, and that may itself have a salutary effect.

* 'The Practice of Management' (Heinemann).

* 'The Business of Management' (Pelican).
† 'Automation—Men and Money', 27–30 June. For further details see p. 4.

LETTERS to the EDITOR

Control put in its place

SIR: Current doubts about the epistemological relationship between Control Theory and Cybernetics, expressed by Stafford Beer and also by 'Pick-off' in your April issue, are based on a misconception reminiscent of that now fashionable controversy about the relative importance of Science and the Humanities. The term 'Science' originally referred to all kinds of systematic studies and what is now described as Science was, until 200 years ago, more correctly known as Natural Philosophy. As such, it represented an outlook on nature, rather than a profession.

But today, both parties to the controversy think of the scientist as a hitherto undervalued specialist, analogous if not equal to a lawyer or clergyman. If we feed him better he will multiply and all will be well! Unfortunately many so-called scientists share this narrow view of their work.

Actually, the scientific outlook maps out an approach to nature which can be described by the simple sequence: collecting and classifying of demonstrable facts; guessing at generalized relationships between them; testing such guesses against the relevant facts; publication of such tested generalizations; and their use in practice, until disproved by further facts.

But this approach can be used in practically all man's activities and in all professions; it is not confined to the subject matter of 'Science' courses. Thus, while it might help to have more scientists in boardrooms and in Parliament, it would be more to the point if all prospective managers and politicians were trained to use this scientific approach to the world's problems.

Similarly, while all so-called control theory is necessarily part of cybernetics, most control engineers confine their interests to the mathematical analysis of fairly simple programme-controlled systems. Cyberneticists—like 'scientists' in that other controversy—have acquired an aura of long-haired, slightly cracked, unworldliness, evoking a pitying smile from hard-headed realists; or, at best, a pat on the head for each new gadget. Many of them, no doubt, deserve this attitude, but the hard-headed boys are throwing out the baby with the bath water, like those who equate science with the Hydrogen Bomb.

The solution is not one bearded cyberneticist in every control engineering firm: we have to persuade every control engineer what cybernetics has to offer him; and also what he has to offer in return. Just suppose, for instance, we could make an analogue computer as small, cheap and versatile as a neuron! But to learn what makes the neuron tick, the physiologist desperately needs the help of the control specialist.

Cybernetics, when all is said, is simply the scientific approach to control problems wherever these occur.

E. G. SEMLER

Purley, Surrey

SIR: I am glad to see that Mr. Stafford Beer admits at last* that he is doing the very same thing against which I protested in my first letter to you (July 1960 issue, page 81), namely, taking a noun with an established meaning and deriving from it an adjective to which he gives a highly specialised and narrow meaning. To do so is not "a shorthand", it is a highly confusing perversion of language, certain to add to the difficulties when we try to convey the developing theories and techniques to those who must help in applying them. If a new adjective is needed to describe formalised control principles, let us coin a new word.

Moreover, Mr. Beer's argument is not consistent, for in his paper presented at the 1956 International Congress he uses "cybernetic" *to distinguish* a probabilistic machine from a deterministic machine—yet the principles of both are recognised and Mr. Beer gives explicit and formalised expressions for both types of machine. Thus on his own arguments we have at least three meanings of the word, one of which he admits is redundant.

Possibly one of your readers who has followed this correspondence from the beginning would care to suggest a formal expression for establishing, on a probabilistic basis and with due consideration of syntactic elements, the pragmatic meaning given to the word "cybernetic" by Mr. Beer when he uses it on any particular occasion. I fear that the difficulty would lie in establishing a basis of probability where there are no recognisable principles.

JOHN B. RUDKIN

Bishop's Stortford, Herts.

* *Letters*, April 1961, p. 81.—EDITOR

Fitting questions

SIR: The figures queried by Mr. McAllister* for panel spacing have been checked and are correct, bearing in mind that the space allocated to any instrument must include an adequate allowance for ventilation, fixing, etc. When this information was being obtained for the survey, it was noted that, for obvious reasons, the dimensions given for panel spacing were often similar to those quoted for the minimum spacing between centre lines.

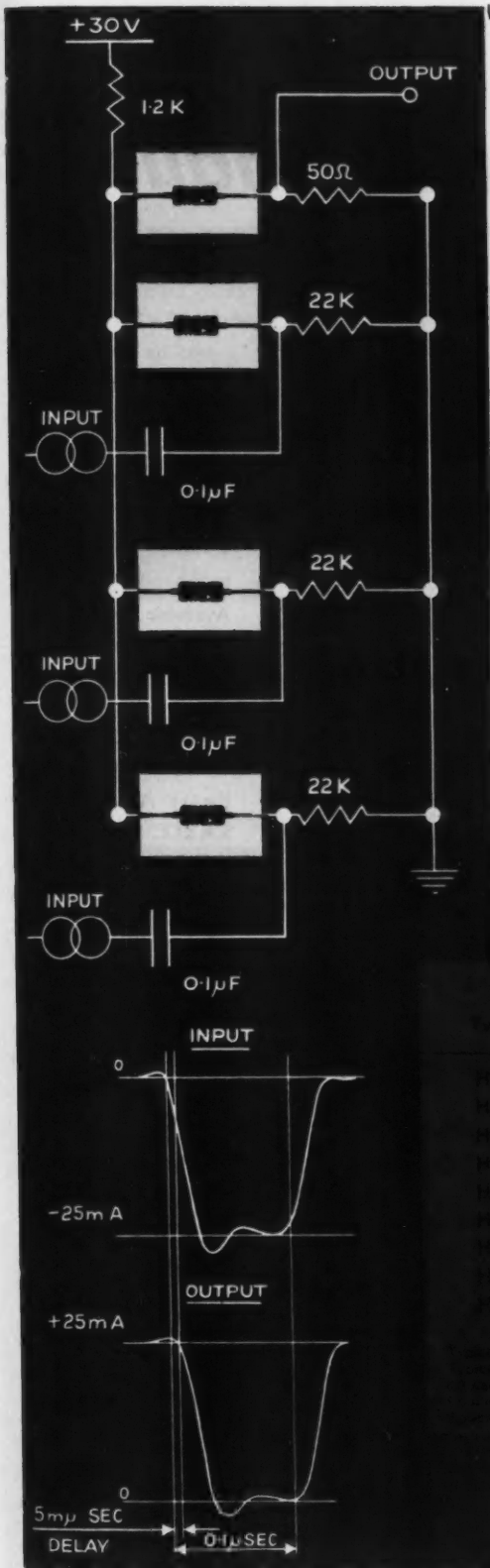
The second Recorder mentioned does not in fact have a bezel but, if required for panel mounting in numbers, they can be located on a common plate or cradle in a manner similar to that employed for mounting amplifiers, servo multipliers, etc. on analogue computers.

The second column was sub-headed "Width and Height" so that the information given for the Swartwout clearly indicated which dimensions were vertical and which were horizontal. This information has also been checked with the manufacturer concerned and found correct. Obviously in certain cases the figures for panel spacing can be varied slightly and any specific application should be discussed with the manufacturer concerned.

J. R. SPENCER

London, E.C.2

* *Letters* last month.—EDITOR



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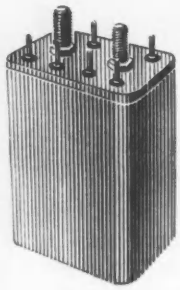

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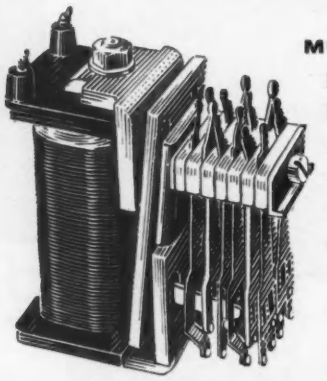

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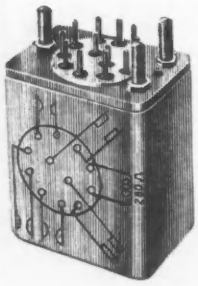
Twinned platinum contacts on light duty versions.

Available sealed, or unsealed with dustcover.



MINIATURE TYPE CC

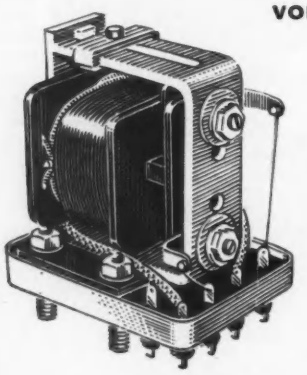
Meets RCS 165 and MIL-R-5757 Specifications.

Based on Type CA magnetic circuit, providing up to four light or medium-duty contact sets.

Available sealed, or unsealed with dustcover.

Printed circuit versions available.

Contact loadings up to 10A d.c., non-inductive, can be arranged for Types CA, CB, and CC.



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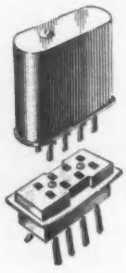
Fully Approved to S.R.D.E. Spec. 166/1.

Temperature compensated in range −40°C to +85°C.

Available for 6, 12 or 24 V operation.

Typical changeover voltage differential 1 V in 24 V.



SUB-MINIATURE TYPE CE

Occupies less than ½ square inch of chassis area.

Two changeover contacts rated 0.25A at 28 V d.c.

Insulation proof against 500 V a.c., r.m.s. between coil and contact stack.

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VIEWPOINT

Dr J. Thomson, Director of the British Scientific Instrument Research Association, disturbed by the quality of scientific leadership, urges the need for men who can see . . .

THE WOOD *and* THE TREES

If I have any particular viewpoint with regard to the instrumentation and control industries in this country at the moment, it is concerned with the quality of their scientific leadership. It is in this field that we are lagging behind other countries, and the Scientific Instrument Research Association, together with the Scientific Instrument Manufacturers' Association, have combined over the past year to give the Minister of Education as clear a picture as possible of the type of scientist required for research and development.

While our universities are still much concerned with turning out the maximum number of 'high fliers', industry is becoming increasingly aware that the university concept of a 'high flier' is altogether too limited when applied to industry. Of course, we desperately need men of originality and intelligence who have a profound knowledge of a particular scientific discipline, for such men occasionally make the important discovery which results in a major break-through. But even more desperately do we need the scientific leader, again with originality and intelligence, but also with the ability to control and direct a project team, and with the breadth of education to see the importance of economic factors and disciplines other than those in which he was trained. To provide this class of super-scientist a new educational approach is necessary, an approach which is more likely to come from the colleges of advanced technology than from the universities, and it is hoped to make a modest beginning with such a scheme at the Northampton College, London, in 1962.

As a nation we have so far had a somewhat haphazard approach to scientific work—a tendency to regard the leaders of scientific thought as men who should not be trammelled by any consideration other than that of advancing knowledge. And yet our history has proved time and time again that the greatest scientists were men of severely practical bent who always had an objective, *but*, an objective which was not necessarily scientific. An examination of the lives and works of men like Faraday, Kelvin, Lister and Brunel, shows that they were motivated by forces outside the realm of science and that those forces were entirely beneficent. What we must now do is make our scientists aware of the importance of other disciplines and non-scientific factors in life, to enable them to see the whole rather than an infinitesimal part, and to guide them towards the successful leadership of specialists. The work of the joint committee of Sira and Sima will, it is hoped, go some little way towards achieving this.

J. Thomson.

Sizing, coating, impregnation, deposition, galvanizing—all done under automatic control. This article describes the method and some of the many applications

Automatic control of impregnating and coating processes

by **E. H. JONES** F.Inst.P., F.T.I., *The Shirley Institute*

IN CERTAIN CONTINUOUS INDUSTRIAL PROCESSES, IT is very desirable to impregnate or to coat a running sheet of material with an additive substance in such a way that a prescribed amount of this substance is applied per unit area, length, or weight of the material. The process usually comprises passing the material through an 'applicator', such as a bath equipped with a roller-nip, which applies the substance to the material as a solution, suspension, or melt. Examples of such processes, briefly dealt with in this article, occur in the sizing of warp yarns before weaving, the application of finishes to cloth, the back-sizing of carpets, the sizing and coating of paper, the impregnation of plastics sheet with softeners, the bonding of staple tissues and fleeces, the deposition of adhesive during the manufacture of abrasive paper and cloth, and the galvanizing of steel strip.

It was largely in connexion with the problem of applying a predetermined percentage of size to warp yarns that the basic principles of the systems of control described in this article were worked out and developed at the Shirley Institute, and devices using these principles are now being made and used under licence.

A warp sheet consists of several thousands of yarns lying side by side. The usual method of applying the size is to run the warp sheet continuously through a bath of hot sizing paste, consisting largely of a solution of starch, and to mangle off the excess of paste which runs back into the bath. The warp sheet is then dried over steam-heated cylinders. The percentage of dry size with which the warp is loaded as it leaves the sizing machine can be affected very considerably by variations in the mechanical conditions of application, the absorbency of the warp, and the properties of the size paste. In practice it is not normally possible to standardize all these conditions, and, until the introduction of automatic take-up control, it was usual for the operative to adjust the concentration of the size until the 'feel' of the warp was considered correct. As there is no sufficiently simple practical method of determining, by continuous observation of the warp, how much size is being applied, the usual feedback methods of control cannot be used.

To overcome these difficulties, novel control systems were devised (*1*). The general principles involved in these systems will be discussed before describing various applications, including the application to warp sizing.

GENERAL PRINCIPLES OF CONTROL

All the automatic control methods dealt with in this article employ the general principle of feeding the additive substance to the bath or other applicator so that it arrives at the rate at which it is desired that it should be taken up by the moving material. At the applicator, where the substance is applied to the material in liquid form as a solution, emulsion or melt, means are provided for detecting changes in the weight (or volume) of liquid in the applicator,* and, if the weight is found

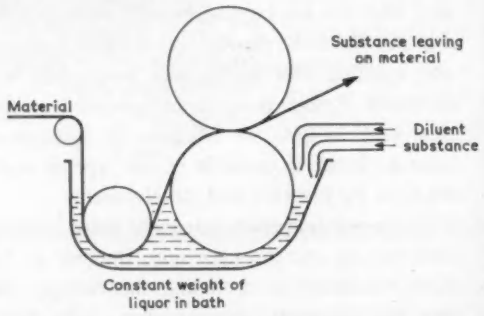


Fig. 1 Principle of automatic control system operating on liquor concentration

to be changing, the change is used to adjust automatically, in a direction to oppose the change, some factor affecting the take-up of the substance by the material. In this way the material is eventually forced to take up the substance at the rate at which it is being fed to it, i.e. at the desired rate. Whatever factor is chosen, the automatic system, by operating on this particular factor only, then compensates completely for the effect on take-up of any variations that may occur in all other factors.

The mathematical theory of these methods of control has been given in previous papers (*2*, *3*) and will not be

* An exception to this occurs where the amount of liquid (e.g. its depth) in the applicator is the factor actually operated upon to control the take-up, as in the galvanizing of steel strip described at the end of the article.

discussed here. It should be mentioned, however, that, in explaining the systems either mathematically or in less precise terms, the factors operated upon to effect control fall conveniently into two classes—those in which the factor chosen is the concentration of the liquor in the applicator and those in which the concentration of the liquor normally remains constant and the take-up of substance is controlled by operating on some other factor, usually one imposed by the machine.

CONTROLS OPERATING ON CONCENTRATION

These systems use the fact that, except in very unusual circumstances, any change in the concentration of the impregnating or coating substance in the liquor in the bath causes a change, in the same direction, in the take-up of substance by the material passing through the bath. The stock liquor metered to the system must therefore have a concentration higher than would ever be required in the bath when applying the desired percentage of substance to the material. Control is then exercised by running diluent into the bath and mixing it with the working liquor so as to maintain a constant weight or volume of liquor in the bath. Fig. 1 illustrates this principle. It will be seen that, with such a control system, any change in the conditions which tends to cause the additive substance in the liquor to be taken out of the bath by the material at a different rate from that at which the substance is being metered to the bath, immediately initiates a change in liquor concentration which tends to counteract the effect on take-up of the changed conditions of application. As the rate of metering of the substance is set to be equal to the rate at which it is specified that the substance should be taken up by the material, it follows that the controller will always operate so as to force the material to accept the specified percentage of substance.

The system possesses inherent regulating properties in which, after a disturbance, equilibrium is restored by continuing to pass material through the bath. The weight of material which has to pass in order to restore equilibrium is proportional to the absolute quantity of liquor maintained in the bath, and it depends also on the relationship existing between the liquor concentration and the take up of substance by the particular material being processed. For rapid response it is therefore necessary to minimize the capacity of the bath.

Warp sizing and cloth finishing

Fig. 2 shows diagrammatically the essential features of the Shirley automatic size box for controlling the amount of size applied to warps before they are woven. The stock size of standard concentration is drawn from the ring main by a metering pump (*4*) which delivers a fixed volume of stock size per revolution. The metering pump is driven from the machine through two positively-infinitely-variable (p.i.v.) gears connected in series. The concentrated stock size from the metering pump passes into a chamber where it is mixed with the water diluent

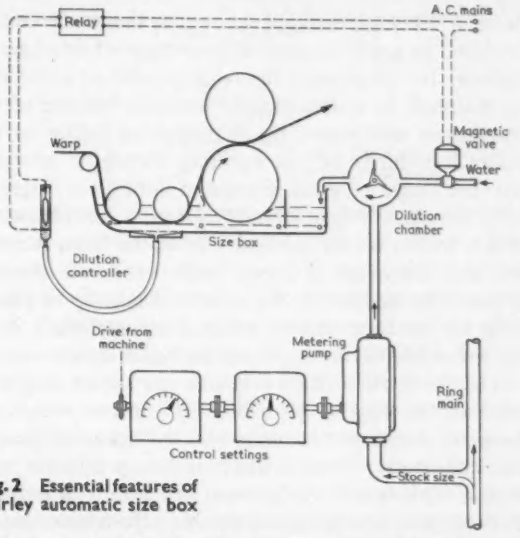


Fig. 2 Essential features of Shirley automatic size box

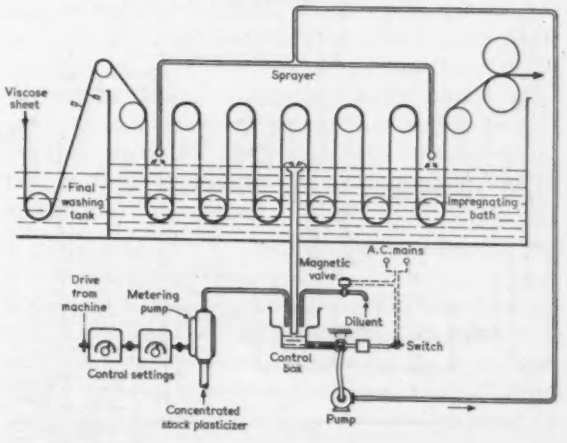
before it reaches the size box. The supply of water is regulated by the dilution controller (*2*). This is essentially a sensitive switch, operated by the pressure of liquid in the size box so that the magnetic valve controlling the water supply is opened as required to maintain a practically constant weight of liquid in the box. The control knobs of the two p.i.v. gears are calibrated so that they can be used to regulate the supply of concentrated size for different percentages of applied size and different linear densities of warp.

Control equipment based on the Shirley automatic size box has been designed to control the application of crease-resisting and other types of finishes to cloth (*5*).

Plasticizing of viscose sheet

The application of plasticizer in the continuous manufacture of viscose sheet is another process which lends itself to automatic control. The impregnation is usually done at the casting machine while the washed sheet is still in a wet condition. The problem is one of maintaining, for very long periods, a given take-up of plasticizing substance, by the same kind of material,

Fig. 3 Automatic control system operating on liquor concentration in plasticizing of viscose sheet



from a starting condition for which the concentration required to apply the desired percentage of substance is known. In this process, the required take-up is difficult to maintain by non-automatic methods because of the continuous dilution of the impregnating liquor by the water introduced by wet material. However, provided that the weight of water introduced in this way, together with the small weight of concentrated stock plasticizer which has to be fed continuously to the bath, remains less than the weight of liquor finally left on the sheet as it leaves the applicator, the control of take-up of plasticizer by the sheet can be maintained indefinitely by a system regulating the impregnating liquor concentration.

The essentials of such a system are shown diagrammatically in Fig. 3. An effectively constant weight of liquor is maintained in the system by means of a small separate control box (*5*) which acts as a dilution controller. This box is swung from one arm of a balance and the other arm is loaded with an adjustable counterpoise. A mercury switch is arranged so that an upward motion of the box, resulting from a reduction in weight of liquor below a predetermined value, operates the switch and opens a magnetic valve so as to introduce water or other diluent. The liquor is kept in continuous circulation between the control box and the impregnating bath by means of a pump of sufficient capacity to maintain a rate of flow of liquor in excess of the rate at which liquor is taken up by the moving viscose sheet. This pump, which is flexibly connected to the control box, draws liquor from the box and sprays it into the bath. The overflow of liquor from the bath runs into the control box, where it is mixed with the metered concentrated stock plasticizer and with any diluent which may be required to maintain a constant weight of liquor in the control box. The metering of the stock liquor is regulated by setting the graduated control knobs of the p.i.v. gears, as with the Shirley size box.

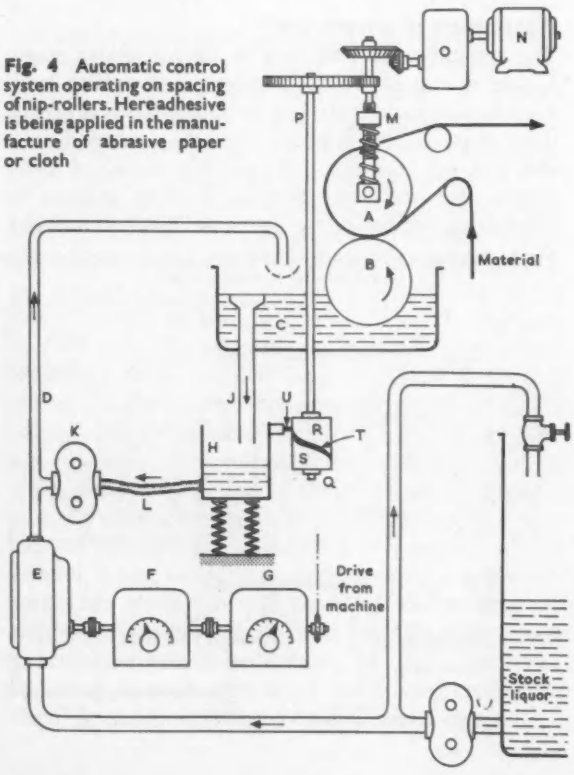


Fig. 4 Automatic control system operating on spacing of nip-rollers. Here adhesive is being applied in the manufacture of abrasive paper or cloth

Bonding of glass fibre

A process in which automatic control of the take-up has worked very successfully is that of bonding glass fibre tissues and fleeces with adhesive. In order to preserve the open texture of the fleece, roller nips cannot normally be used to squeeze off the excess liquid. In one method, a liquor containing the adhesive is applied to the loose fleece, in excess of its requirements, while the fleece, supported on a perforated conveyor through which excess of liquor is drawn off, passes through the machine. The percentage of adhesive to be left on the fleece after drying then depends largely on the concentration of the liquor. For automatic control, arrangements are made to circulate the liquor continuously through the fleece by way of a control box which receives and mixes together all the excess liquor drawn off from the conveyor, the concentrated stock liquor metered to the system, and the diluent. As in the previous application, the amount of diluent added is controlled to be just sufficient to maintain an effectively constant volume or weight of liquor in the control box.

CONTROLS OPERATING ON OTHER FACTORS

When the factor which is to be operated upon is one other than the liquor concentration, a more rapid response is usually possible. This is because the absolute amount of liquor in the system has no longer any effect on the response rate, which is now governed largely by the built-in relationship between small changes in the amount of liquor in the system and the corresponding changes in take-up of liquor imposed by operating on the chosen factor.

Nip-roller control

The take-up of substance by a material passing between rollers forming a nip can be controlled over a limited range by changing the spacing of the rollers at the nip, either by making a deliberate change in the distance between the roller axes, or by altering the thrust between the rollers. Either of these factors can be operated upon automatically to control the 'lay-on' of an adhesive, such as glue, during the manufacture of abrasive paper and cloth (*6*). Fig. 4 shows basic equipment for doing this. The material is coated on one side only by passing it round the upper roller *A* of a pair of squeezing rollers *A* and *B*. Roller *B* rotates in the adhesive liquor contained in the pan *C*. Fresh liquor is metered to the pan, through the pipe *D*, at the desired rate of application, by means of the metering pump *E* driven from the machine through the p.i.v. gears *F* and *G*. A control box *H*, of small capacity, and supported on suitable springs, is mounted below the overflow-pipe *J* leading from the pan. A circulating pump *K* draws

liquor continuously from the control box through the flexible pipe *L* and delivers it into pipe *D*. Take-up is automatically controlled by using small changes in liquor weight in the control box to act upon the screw-jack mechanism *M* which controls the spacing of, or the force between, the squeezing rollers. The screw-jack is driven by a reversible pilot-motor *N* operating through a suitable speed-reducing gear-box *O*. The setting of the screw-jack is transmitted to the control box by the rotation of shaft *P*, which makes rather less than one complete revolution for the whole range of setting of the screw-jack. Drum *Q*, mounted on shaft *P*, is made largely of insulating material, but its surface is covered by a layer of metal divided into two electrically disconnected sections, *R* and *S*, by a narrow helical track *T* of hard insulating material, the surface of which is flush with that of the metallic covering. A spring-loaded conducting brush *U*, slightly narrower than the helical track, is mounted at the side of the control box so that it presses continuously against the drum. Electrical connexions from the drum sections and the brush are so arranged that, when the brush is in contact with the upper section *R* (indicating that too much liquor is being taken up), the pilot-motor is switched on to decrease the spacing between the rollers, and, at the same time, the drum is rotated until the brush moves on to the insulated track *T*. In a similar way the roller spacing is increased if the brush moves on to the drum section *S*. The mechanism thus establishes a definite relation between small changes in the weight of liquor in the system and the spacing of the coating rollers or the force between them. By proper choice of this relation, lay-on can be stably controlled, with fast response.

Back-sizing of carpets and coating of paper

In the continuous back-sizing of carpets, a stiffening substance (starch or rubber latex) has to be applied to the underside of the carpet. The method of doing this is shown in Fig. 5. The back of the carpet passes over a furnishing roller *A* which lifts the coating liquor from the trough *B*. The amount of liquor applied can be controlled either by changing the speed of rotation of the furnishing roller or by adjusting the height of a doctor-knife *C* which scrapes excessive liquor off the carpet and returns it to the trough. Automatic control of the weight of coating applied can be achieved by metering the coating liquor to the trough, so that coating substances arrive at the desired rate, and then adjusting the speed of the furnishing roller (or the height of the doctor-knife) in accordance with small changes in the weight of liquor in the trough. Suitable mechanisms for doing this have been devised (7).

A somewhat similar control system can be adapted to the sizing and coating of paper.

Continuous galvanizing

In the continuous galvanizing of steel strip by the 'hot-dip' process, depicted diagrammatically in Fig. 6, the pre-heated strip is passed through a galvanizing pot *A*

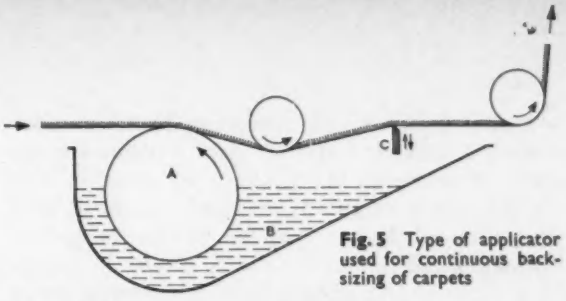


Fig. 5 Type of applicator used for continuous back-sizing of carpets

from which it emerges vertically through the nip of a pair of partially immersed exit rollers *B* and *C*. The force at the nip is determined by the position of the weight *D* along the lever *E*. The level of the molten zinc alloy in the pot largely determines the depth of the alloy in the wedge-shaped space *F*, above the nip, through which the strip passes immediately after it leaves the nip on its way to the cooler. For a given force at the nip, this depth controls, to a great extent, the weight of zinc coating applied per unit area of steel surface. In controlling the process manually, the operative attempts to maintain a constant depth of alloy in the space *F* by introducing ingots of alloy into the pot from time to time. Although this procedure may result in a reasonably uniform coating, it does not allow the absolute weight of alloy applied per unit area of steel surface to be controlled at a predetermined value. In order to achieve such control automatically it is necessary to meter the alloy to the pot at the desired rate of deposition.* Metering devices can be arranged to deal with

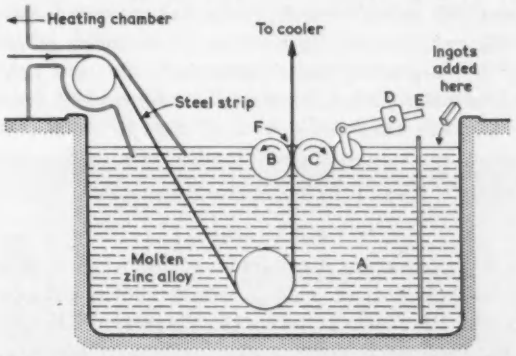


Fig. 6 Type of applicator used for continuous galvanizing of steel strip in the 'hot dip' process

the alloy in the form of ingots of uniform weight, pellets, wire or strip. As the factor which is operated upon in this particular application is the depth of liquor itself, the regulator assumes a very simple form; it does, in fact, acquire inherent control properties because, without additional equipment, the depth of molten alloy in the space above the nip automatically adjusts itself to that required to maintain the predetermined rate of application of the coating.

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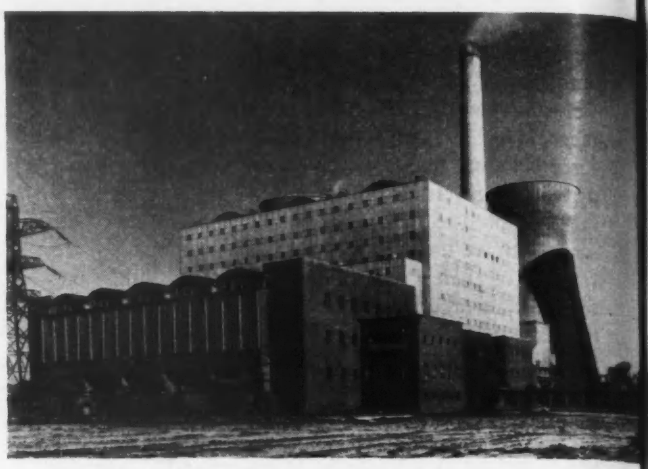
* Patent applied for.

PART 2

Computer operation promises lower running costs and greater safety for personnel and plant



Operating a power station with a computer

by **A. J. WAKEFIELD** B.A., D.Phil.
Panellit Ltd

Last month we considered how a modern power station is run. We gained some insight into the instrumentation problems by considering portions of a complete generating set, examining more particularly the path taken by feed water during its conversion into working steam. We then discussed the input from plant to a 609 computer, going on to consider alarm detection, logging, and other facilities of the system.

TIME SHARING

The 609 system can scan points on line without interruption by means of a device which interleaves scanning with other tasks performed by the system. The load on the machine is greatest when several events occur simultaneously. For example, if a group of points is becoming off-normal, a log is printed and a manual demand is set on the control panel, all in parallel.

The 609 senses whether input or output devices are held up or free. Thus if alarm scanning is held up while the next point is being selected on the switch, the 609 is free to proceed with other routines; for example, a printing routine. The printing routine contains frequent tests to determine whether the selector switch is free. When it becomes free, the 609 ' remembers ' the place it had reached in the printing routine and returns to alarm scanning, which is of higher priority. In a similar manner, a number of distinct routines can proceed concurrently, and priority it taken into account.

In normal scanning and printing, which occupy the machine for most of the time, the program is unsophisticated and does not fully occupy the computer time available between successive switchings or character-printings. Thus the capacity of the machine is usually limited by the speed of the selector switch and printer rather than by that of the computer.

INSTRUMENTATION FOR AUTOMATIC OPERATION

At the present time, the 609 is being considered for two 100 MW solid-fuel-fired generating sets, in more advanced applications than have been described above. Before describing the path to fully-automatic operation, let us see what additions are required to the instrumentation which links a computer and plant.

Clearly, a larger number of analogue inputs will be needed. In monitoring, the actual settings of the valves, dampers and set points of local controllers do not interest the 609 directly. They are recorded and logged primarily for historical purposes. The interesting measurements indicate the *result* of operating at these settings rather than the settings themselves. In automatic operation, the actual settings must be ' input ' to the computer. Also, many measurements are of interest during a limited portion of starting or actual operation only. For example, in a p.f.-fired station which is started on oil fuel, the pressure of fuel oil and atomizing air is mainly of interest during lighting-up of the burners. Similarly, the bunker level is not of interest if there is enough for the shift. In a manually operated station, these quantities would not be chosen as log or alarm points since they occupy the operator's attention only at a specific time.

Apart from analogue inputs, there will be many

on/off inputs. These arise because many valves and dampers are intended to be kept fully open or fully closed. Also, some analogue quantities, such as lubricating-oil pressures, are abnormal if *below* and all right if *above* a minimum; the actual value is thus not of interest.

Also there are numbers of indications which show that the plant is available or not available. For example, there are numbers of isolating valves which permit maintenance on a section of the plant. Also many fans, pumps and other auxiliaries can be isolated from the mains and reconnected before starting can proceed.

There is a hard core of measurement for which techniques have not yet been perfected. For example, proof of ignition of burners and correctness of flame-shape present considerable difficulty.

STARTING ON OPEN LOOP

The most critical test for an automatic control system in a power station will be starting. Starting when the boiler is warm, that is, when there is positive steam pressure in the boiler, is easier than a cold start, in which additional operations are required to expel air and drain water from the system. Also, the warm start is the most likely kind because the most fruitful application for automatic starting is in fact two-shift operation, and the typical length of shut-down will be eight hours on week-days and two days at week-ends. We shall here confine our attention to the warm start.

The scheme outlined below is a series of steps in which the computer is given the task of *guiding* the operator (instead of *replacing* him) in certain parts of the sequence, and thus demonstrates its ability actually to control the plant.

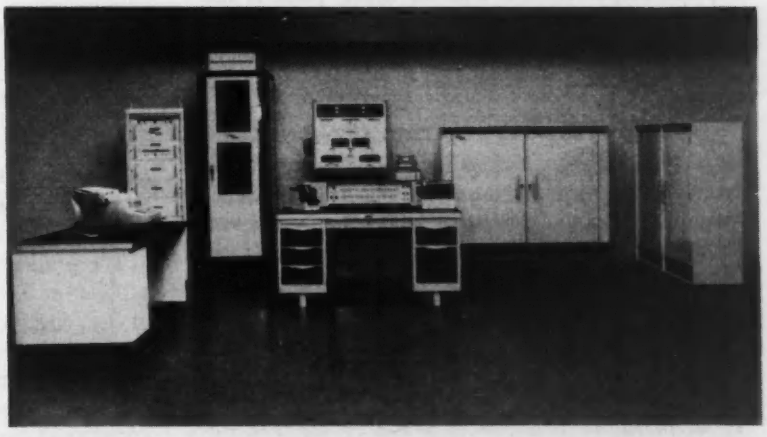


Fig. 3 A 609 system that logs 450 plant temperatures. Such 609 systems are designed for time-sharing operation, on line with the process that is being controlled

The first task is to determine whether the set can start up and meet a given load by the stated time at which a demand is received. This involves determination, by temperature and pressure measurements, of the heat left in the boiler. The known maximum rate of increase of temperature is specified, and it is possible to calculate whether working conditions can be reached in time. A definite time is allowed also for the preparation of the boiler and auxiliaries before ignition. Also, since it is not economical to start the boiler too early if there is time to spare, the computer can determine the latest time at which to begin the starting sequence. The advantage of carrying out each step of the starting sequence as late as possible is in the minimization of power consumption by auxiliaries.

Apart from thermal considerations, availability of plant is also necessary. If the use of an auxiliary is not imminent, there may be a very good reason for it being unavailable; for instance, it may be isolated for maintenance. Before starting up, the computer can check and print (as a warning to the operator) a list of all auxiliaries which are isolated or tripped. Sometimes, if an item is not available, the plant can be operated on part but not on full load. In some cases there is spare capacity, and since the total running time of each piece of equipment since its last overhaul can be 'remembered' by the computer from shift to shift, duplicated auxiliaries can be used in such a manner as to equalize running hours. At this time other essentials can be checked, such as instrument air-pressure, feed-water pH and conductivity, oil-level in tanks, and fuel-content in hoppers.

The next step is to extend conventional monitoring to include the additional computer inputs which have been provided. This makes monitoring possible during starting-up as well as under the more usual steady conditions. However it is more complicated, because alarm limits will vary as the sequence progresses; also on/off valves and dampers will be open for part of the sequence and closed for the remainder. The actual operation of starting up will be carried out by the operator; but the computer checks that the state of the system is correct considering both the time elapsed and the actions already performed by the operator.

The next step is to store a sequence of operations in the computer's memory for starting the boiler, and check the actions of the operator against a stored sequence. If he carries out steps in the wrong order, or fails to switch on an auxiliary at the appropriate time, an alarm is sounded.

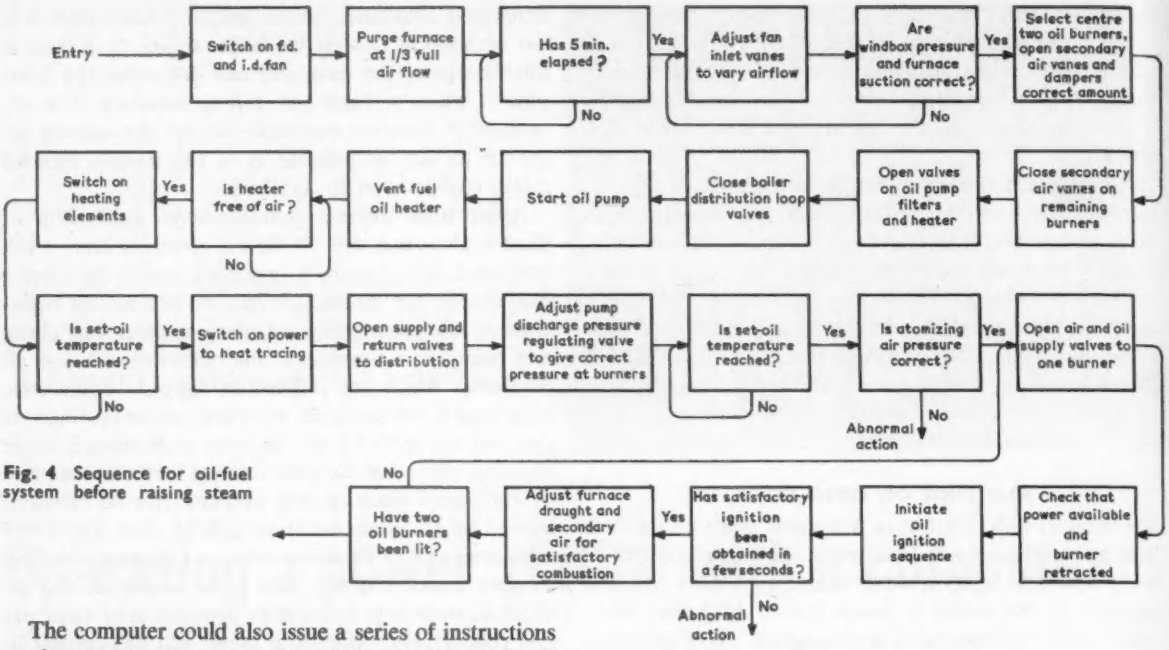

Entry
Switch on f.d. and i.d.fan
Purge furnace at 1/3 full air flow
Has 5 min. elapsed?
Yes
No
Adjust fan inlet vanes to vary airflow
Are windbox pressure and furnace suction correct?
Yes
No
Select centre two oil burners, open secondary air vanes and dampers correct amount
Close secondary air vanes on remaining burners
Open valves on oil pump filters and heater
Close boiler distribution loop valves
Start oil pump
Vent fuel oil heater
Is heater free of air?
Yes
No
Switch on heating elements
Is set-oil temperature reached?
Yes
No
Switch on power to heat tracing
Open supply and return valves to distribution
Adjust pump discharge pressure regulating valve to give correct pressure at burners
Is set-oil temperature reached?
Yes
No
Is atomizing air pressure correct?
Yes
No
Abnormal action
Open air and oil supply valves to one burner
Check that power available and burner retracted
Initiate oil ignition sequence
Has satisfactory ignition been obtained in a few seconds?
Yes
No
Abnormal action
Adjust furnace draught and secondary air for satisfactory combustion
Have two oil burners been lit?
No

Fig. 4 Sequence for oil-fuel system before raising steam

The computer could also issue a series of instructions to the operator on a typewriter. When an instruction is given, such as 'switch on an i.d. fan', the operator obeys it. The carrying out of the instruction is followed either by an acknowledgement or the next instruction. Before giving an instruction, the computer checks that all previous instructions have produced the correct result and that the plant is behaving in a healthy manner. The behaviour of the system is the same as under full automatic control, except that the link between the computer output channel and the actual plant is the operator, instead of a selection matrix and output devices including solenoids, control valves and damper motors.

FULLY AUTOMATIC STARTING SEQUENCE

The starting sequence itself is far more detailed than a mere time-table for switching on various auxiliary items of equipment on the generating set to supply a given load demand. When the computer is not engaged on the sequence for starting, there are measurements on the complete system to ensure that it remains healthy, and that steps have been carried out correctly. The operations carried out by the program can be classified as follows:

1 Advancing the starting sequence step by step until the boiler can attain full load.

2 Checking that the preceding step has been carried out correctly. Each step leads to the issue of a computer output. Following the output, one or more input points will be checked to determine whether it has produced the correct result or not. For example, after starting an f.d. fan, the pressure difference between inlet and outlet is measured to prove that the fan is operating correctly. Opening or shutting a solenoid valve will close contacts, thus energizing certain inputs to the computer.

3 Halting the sequence until a specified value of some measurement is attained before carrying out the next step.

4 Ensuring that individual items remain healthy. If an item becomes unhealthy, one of the following four courses should be followed:

(i) Halt the sequence until the fault has been put right.
(ii) If there is a stand-by item, withdraw the unhealthy one and bring the stand-by in.
(iii) If there is no stand-by, halt the sequence and begin an abnormal shut-down.
(iv) Return to an earlier point in the sequence and pursue the previous sequence, or an alternative sequence, until the point of difficulty has been successfully negotiated.

COMPUTER REQUIREMENTS

For automatic operation, the 609 data-logging computer will have to be extended in several directions from the specification given earlier under *The 609 system* (last month, p. 87). Both analogue and on/off outputs must be provided. The total number of inputs and outputs will be about a thousand, subject to reduction owing to any interdependence.

The program will be lengthy; even if the start-up is assumed to be uneventful, the complexity exceeds that of data logging. Whereas the latter deals with a plant whose items will normally all be operating, the former has to monitor a piece of equipment in which many items are irrelevant at the start and are gradually introduced until normal load is reached, while others are relevant in the early stages and are discarded later. In addition, the alarm limits used in monitoring the plant at any stage vary because the equipment is heating up, or is otherwise used in an unsteady condition. The monitoring section of the program thus deals with a changing list of points and alarm limit values for each step of the sequence.

Study of the starting-up problem shows that the central computer is adequate in speed. Although the program is complex, most of the time is occupied with

STEP NO.	1	2	3	4	5	6	7	8	9
Alarm scan and log on load	X	X	X	X	X	X	X	X	X
Alarm scan during starting						X	X	X	X
Determine ability to meet load demand in time		X	X	X	X	X	X	X	X
Availability check on plant			X	X	X	X	X	X	X
Check manual operation against stored sequence				X	X	X			
Issue instructions to manual operator					X	X			
Automatic start for normal case							X	X	X
Auto-start for abnormal cases									X
Fully auto-control for efficiency on load								X	X

Fig. 5 Steps in evolution of computer control for generating set

monitoring. The actual instructions which advance the starting sequence are spread out because the sequence is gradual. Thus, at the comparatively slow rate of one output per second (an 'output' being an alteration to a control setting), the sequence would be proceeding faster than a human operator in a conventional control room could carry it out

The maximum-size random-access store of 8192 words will be required. The program will occupy more than this; so magnetic-film storage will be required to back up the fast-access store. A magnetic film holds 4096 blocks of 64 words each, and a block of information can be transferred to and from the film by a single instruction. A system with several magnetic-film storage channels will have greater flexibility than one with a single channel. The first channel will contain programs for normal operation; a second channel will contain programs for abnormal operation; a third will be used to receive the history of the plant as it is output by the main computer; and a fourth will be used to store data.

In the author's view, the 609 computer is ideal for monitoring and logging in power stations with conventional controls. It can be modified effectively for completely automatic operation when used with appropriate instrumentation.

It is certain that the operations involved in the starting-up of a generating set will need careful analysis if a suitable program is to be perfected. The need is for close liaison between the programmer and the manufacturers of the boiler, turbine and instruments. Analysis will need to be done as thoroughly as for the successful installation of an electronic data-processing machine in a commercial undertaking.

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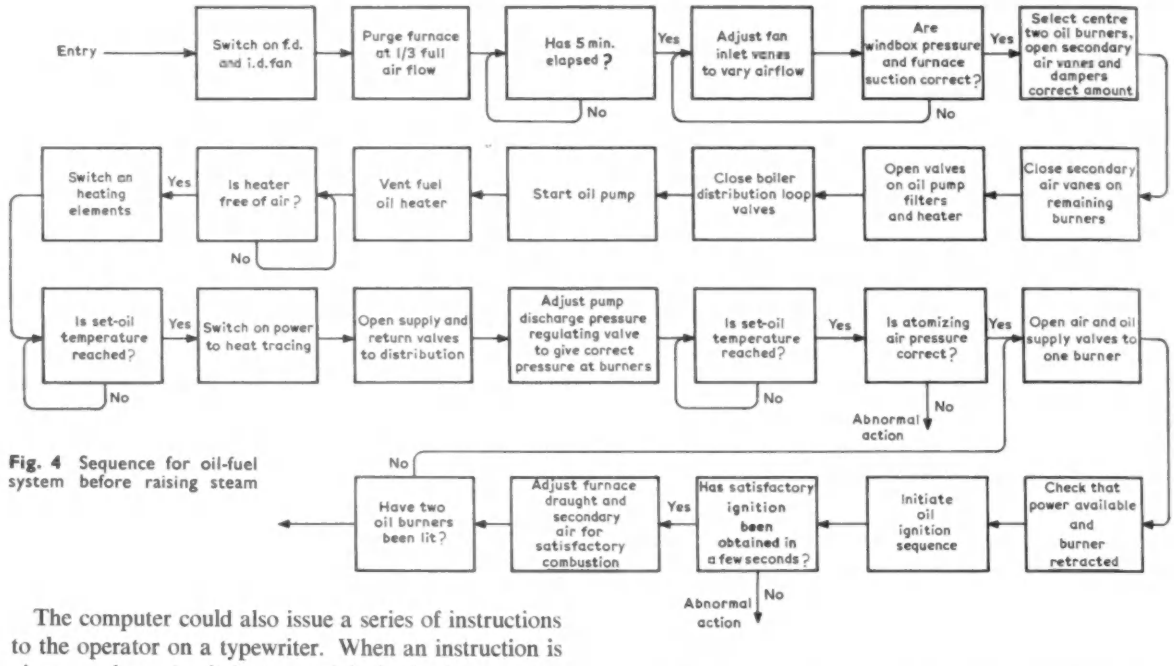
The mistakes made by manual operators include wrong manipulation of controls and errors of judgement; outage of equipment due to such errors will be eliminated with computer control. Similarly, strain on the plant will be reduced because the timing and tighter control of the operating sequence gives smoother operation, which in turn reduces repair costs and premature outages for overhaul. During starting-up, fuel is saved because the set is brought to working conditions more quickly and combustion efficiency is maintained. The shorter starting time means effectively a greater capacity to meet sudden demands for load, which implies a greater return per unit of capital spent on plant.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Availability check on plant			X	X	X	X	X	X	X
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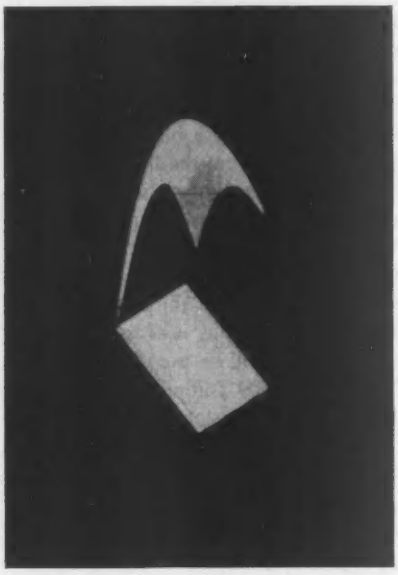


PART 2

In this fast-moving field, it cannot be long before some of the evolving theory finds application: but the practical problems are still severe

Adaptive control

by **J. H. WESTCOTT** B.Sc.(Eng.), Ph.D., M.I.E.E.
Imperial College of Science and Technology

In Part 1 we gave grounds for supposing that a new theory is needed. To show how the framework of this new theory is shaping, we started by considering simple examples of adaptive systems not vulnerable to existing analytical methods. We then stated and discussed the essential components of an evaluative theory, and found that it all sounded quite difficult.

The situation is not quite so unrelieved. It is possible to make some useful engineering simplifications which bring the prospect of a valid theory much nearer. The first of these concerns the statistics of signals. The work is much simplified if the assumption can be made that the signals form a Markoff process. Such a description fits a wide range of engineering circumstances, where the underlying basis is a transition from one state to another. These transitions may be packed closely together without limit, but the essential thing is that each transition is independent of others. The core of the matter is the transition probability between states, and, given these, it is possible to formulate very general partial differential equations expressing the way in which the probability distribution functions vary with time. Since the probability distribution function is the key to any required statement about a variable on the average (such as mean value, mean square value and so on), this is a very far-reaching statement, and, being expressed in terms of amplitudes of the variables, enables one to handle non-linear characteristics readily. A particularly convenient operational formulism for deriving distribution functions of this type has been given by Florentin (E.A.C. paper), based on earlier work attributed to Bartlett. In a simple example demonstrating the method, the resulting equations are of the Fokker-Planck type, linking up with the work of Grensted and Jacobs mentioned earlier. The solution of partial differential equations of this sort is by no means easy, and it is here that resort to digital-computer solution is likely to be necessary. These functions are required in assessing adaptive control in order to know the probability of values of the variables which specify the dynamic state of the system. By their use it is possible to keep track of the drift dispersion of signals as they traverse the system.

Calculation of optimal trajectories

The other great benefit arising from the Markoff assumption is the fact that, in calculating the dynamic behaviour of the system, to be completely up-to-date it is only necessary to take as initial conditions those relevant at the last transition; no further statement concerning past history is necessary. This reduces the variational problem of calculating optimal trajectories to manageable proportions, although the fact that only transition probabilities are specified means that large numbers of individual trajectories have to be calculated. The variational problem would be much simpler if the field of variation were known to be unrestricted by system constants. In this case the classical Euler-Lagrange equations would allow the problem to be formulated and solved. At the Ifac Congress much interest was evoked in Pontryagin's mnemonic for optimal control, using his 'principle of maximum', which has the possibility of being able to handle some system constraints. Recently McCann (E.A.C. paper) has demonstrated, using Legendre's dual transformation, that Pontryagin's method can be derived from the same basis as the classical relationships, but comes out in a form more convenient for inserting constraints. Various ingenious methods of allowing these classical-based

methods to be used on problems involving control variables with limit stops have been suggested, with a view to simplifying the amount of computation that is otherwise required. When such stratagems fail, and a frontal attack is considered necessary, there remains the alternative of applying dynamic programming procedures. These represent a systematic scheme of solving adaptive control problems with the mathematical theory of multi-stage decision processes. The essential link which makes this a possible mode of solution is the Markoff assumption, with its utilization transition probabilities between system states. Each transition possibility is regarded as a decision, and an optimal policy is chosen as the sequence of such decisions leading to an optimum response. An important characteristic of dynamic programming procedures is that the work is carried out backwards. Each transition is treated independently, the aim being to bring the system back to its ideal condition of maximum yield at minimum cost. So the sum is commenced at the maximum-yield state, and in discrete steps the whole sequence of system response trajectories is worked out, going further and further back in time, until the particular initial conditions which prevailed at the transition under consideration turn up at the end of one of these, by now very many, trajectories. All other trajectories, which have incidentally been calculated *en route*, are now abandoned, and the one which matches the boundary conditions is used to prescribe the control variables for controlling the system along the optimal trajectory. As soon as a new transition occurs, the whole procedure must be started again. In an adaptive system some evidence about the system's parameter-changes is obtained from the departure of the system from the expected trajectory. This very prolific computation of trajectories in working backwards is known as the 'flooding' phenomenon in dynamic programming, from its well-known ability to occupy a horrifying amount of computer storage capacity. Naturally, the search for a method of solution making more temperate demands on computing capacity is being energetically pursued. A useful review of methods which seek to avoid the difficulties of computing and realizing the optimal solutions, due to Merriam III and Kalman, has been given by Pearson (E.A.C. paper), who is hoping to enter the lists himself with a method using Lyapounov functions.

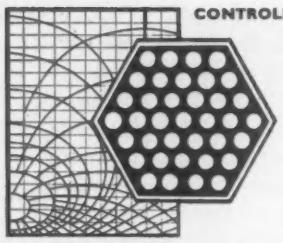
Three major avenues to join

Thus the new theoretical approach to control problems, that is required to make rational design and performance prediction possible, is seen to be taking shape along three major avenues. Somehow these lines of development must be amalgamated into a single comprehensive theory, and the tantalizing research question of the moment is how to do this. The first line is to achieve a closer specification and analysis of dynamic system behaviour, to ensure that response to given control action can be accurately determined. The second is the development of a stochastic theory adequate for statistical estimation and inference theory to be brought to bear on the problem of gathering information for adaptive control. Finally there is the development of efficient variational techniques for determination of optimal control strategies, yielding explicit methods of computing a sequence of control actions to bring a plant to a desired state at least cost, within limitations of given constraints and varying conditions of signal environment.

Practical prospects

In this fast-moving field it cannot be long before some of this theory finds practical application. Already simple forms of on-line computer are being experimented with. It is perhaps useful to draw a clear distinction between the stages in the solution of complex control problems. In the early stages of a study, many data have to be gathered concerning the basic environment and conditions of the problem. These are then analysed off line, and a simulation of the control problem established on a computer. It may be necessary to do this in considerable detail in order to be sure of using a reliable simulation, and to reduce the variance of estimates sufficiently to permit comparison of various proposed schemes of control. This stage of evaluation of control schemes is one for which the new theory is essentially required, and is of particular interest as a fundamental research problem to which the universities can most readily contribute. As an outcome of this process of evaluation a particular control scheme will emerge as best, and it is then necessary to arrive at a form of controller which will represent the structural minimum in physical complication, and which is adequate by engineering standards and on economic grounds as an approximation to the ideal scheme.

Here there is great scope for ingenuity and engineering flair. Ultimately the purpose is to exert control over physical processes, and a substantial practical problem remains after the general requirements on the controller have been worked out. The question of what particular mode of operation should be employed by the controller has to be decided. Where speedy computation requiring boundary-value matching is required, continuous analogue methods of realizing the controller may well be the best and most satisfactory. On the other hand, as accuracy gains the greater importance, a form of incremental computer might be more appropriate. When the requirement is for precision in lengthy computations, possibly at slower speeds, a digital computer will be necessary. In any case, there are still severe practical problems to be faced in ensuring the reliability of the controller, and in designing suitable matching peripheral gear and actuation devices whereby the intentions of the controller are faithfully put into effect on the plant. There is much work still to be done in developing measuring instruments and transducers accurate and robust enough to make precision computer control a practical possibility. *End*



Practical experience at Britain's first nuclear power stations shows which are the important points to watch

Supply and regulation of boiler feed-water

by **J. W. W. SHAW** *U.K. Atomic Energy Authority*

Last month we introduced the problems of feed-water supply and regulation in nuclear power stations, and described briefly the principles of single-, double- and triple-element regulators. We then opened a discussion of feed regulation in relation to reactor control, and referred to the situation at Calder Hall (*see Fig. 7, p. 96*).

Some effects on reactor inlet temperature

Some reasons have already been given why it was considered necessary to keep the temperature of the gas returning to the reactors as steady as possible. There are also certain reactor phenomena which emphasize this requirement; only, in these cases, it is particularly important that the gas temperature does not *rise* above the working level by more than a predetermined amount. Considering only the effects of feed regulation, it will be appreciated that any circumstances which result in a reduction of feed flow will cause a rise in gas temperature, and must, therefore, be considered with special care. We studied such a case when describing the principles of the single-element regulator, namely a reduction in steam pressure together with an increase in steam flow. The net result of this change was to cause swell in the boiler, which in turn reduced the feed flow. An attempt has been made in Fig. 8 to indicate the sequence of events which would follow such a disturbance on the steam side. The interesting feature is that the fall in water level, which results eventually from the increased steam flow and reduced feed flow, has a much more pronounced effect on the gas temperature than the initial swell. This indicates that a set of circumstances which initially reduces the gas temperature may, eventually, cause a more substantial rise of gas temperature. Such appears to be the case, and in Fig. 9 the probable sequence of events is indicated. There are, of course, many more circumstances connected with feed regulation which can cause the gas temperature to rise, but the two examples given are typical. Figs. 10 and 11 indicate the degree of improvement which may result from fitting two-element regulators to cover the two cases considered in Figs. 8 and 9. The curves in Figs. 8, 9, 10 and 11 are not actual results, they merely indicate known trends.

SELECTION OF FEED REGULATORS FOR CALDER HALL

Briefly, the Calder Hall steam-raising plant consists of four heat-exchangers to each reactor, each heat-exchanger containing an entirely separate high- and low-pressure boiler (h.p. 195 lbf/in² gauge and l.p. 48 lbf/in² gauge at superheater outlet). It is a feature of the overall control of the reactors that the h.p. steam pressures remain sensibly constant while the l.p. steam pressures can be varied to keep the reactor-inlet gas-temperature steady. The selection of a central, feed-water pumping station to supply all heat-exchangers at each reactor, placed an exacting duty on the l.p. feed regulators. Not only were they required to operate over a wide pressure-range, but they had to control against very large pressure-drops, with the added disadvantage of steam with high specific volume to accentuate the effects of swell and subsidence. In addition, the regulator had to work out of doors, and without an external power supply if possible. Of the equipment available at that time, Weir's Robot single-element, float-operated, regulator was selected as the most suitable for the low-pressure duty.

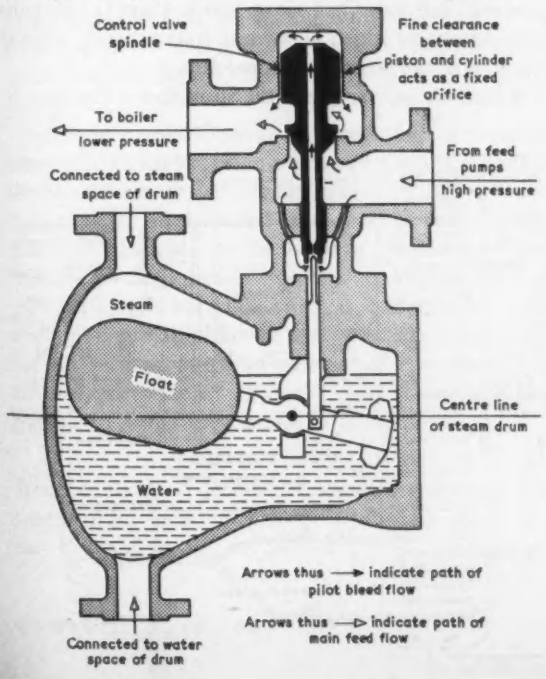
As far as the high-pressure boilers were concerned, the Robot had one disadvantage. It is a combined unit with the feed control valve integral with the float chamber This means that the feed lines must be taken up to the steam drum, where the regulator must be mounted, and back again to the feed injection point. In the h.p. systems, with the steam drums over eighty feet above the feed injection point, this feature was of some importance. Finally, Weir's Steadiflow regulator was selected as being the most suitable for this duty. Whilst it did not have the same operating power as the Robot, it was thought to be adequate for the apparently less exacting h.p. duty. The Steadiflow has the advantage that the float assembly and the control valve are separate units, only connected by a small-bore bleed-pipe, which enables one to mount the float assembly at drum level and the control valve at feed injection level, thus eliminating feed lines up to the drum and back to the feed injection point.

Robot feed regulator

The Robot regulator is normally positioned on the centre line of the steam drum, the mid-point of float travel

coinciding with what is usually referred to as the *normal water level*. The top and bottom openings from the float chamber are connected by pipes of 2in bore to the steam and water spaces of the drum respectively. It will be appreciated that, as the water level in the drum varies, so does the level in the float chamber, and the large-bore connecting pipes ensure that there is very little difference between the two levels. The actual functioning of the regulator will be more readily understood on reference to the simplified diagram in Fig. 4. The control-valve spindle has, in addition to the valve itself, a piston at the top and bottom; the top piston has an effective area greater than the combined effective areas of the bottom piston and valve. When the regulator is controlling the feed flow, there is an appreciable pressure-drop across the valve and this is used to operate the system. It will be seen that a small bleed of feed water can pass through the ports to the chamber below the valve spindle, then on through the needle-valve orifice, up the centre of the valve spindle, to escape between the top piston and the cylinder wall into the low-pressure side of the control valve. The clearance between the top piston and cylinder is small enough to cause sufficient pressure-drop in the bleed flow to maintain the desired working pressure on the top piston. In other words, the clearance between the piston and cylinder acts as a fixed orifice. The diameters of the piston and valve seats are selected so that the valve spindle is in dynamic balance when the pressure above the top piston is approximately mid-way between the feed-lines and boiler pressures. If it is assumed that the assembly is in equilibrium as shown in Fig. 4, and further assumed that the steam drawing-off rate is increased, it will be appreciated that eventually the water level in the drum and the float chamber will fall. This will cause the needle to rise, thus reducing the size of the variable orifice and increasing the pressure-drop across it. This increase of pressure-drop across the orifice will reduce

Fig. 4 Simplified cross-section through Robot regulator


Control valve spindle
Fine clearance between piston and cylinder acts as a fixed orifice
To boiler lower pressure
From feed pumps high pressure
Connected to steam space of drum
Steam
Float
Centre line of steam drum
Water
Arrows thus ⟶ indicate path of pilot bleed flow
Arrows thus ⟶ indicate path of main feed flow
Connected to water space of drum

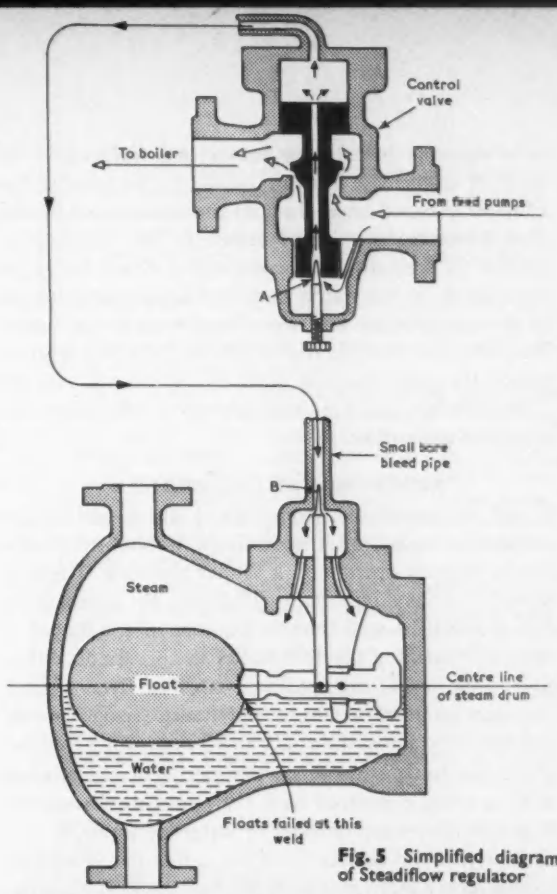


Fig. 5 Simplified diagram of Steadiflow regulator

the pressure on the top piston, and the unbalanced forces will cause the valve spindle to rise. The valve will continue to rise until the orifice returns approximately to its original size and the pressure above the top piston again balances the rest of the system. The opening of the control valve will increase the feed flow, until eventually it will match the increased steam demand. It will be readily appreciated that, had the water level risen owing to reduction in steam draw-off, the sequence of events would have been reversed, causing reduction of feed flow.

Steadiflow feed regulator

The Steadiflow regulator operates on a principle similar to that of the Robot, but consists of two separate units. The float chamber is mounted as for the Robot, while the control valve is inserted in the feed line, close to the feed injection point. The only connexion between the two units is a pilot bleed line of relatively small bore. The principle of operation will be more readily understood by reference to the simplified diagram in Fig. 5.

Bleed water flows from the high-pressure side of the control valve, *via* the needle-valve orifice *A*, up the centre of the valve spindle, through the bleed pipe and needle-valve orifice *B*, into the float chamber. The main valve spindle has, in addition to the valve itself, a piston at each end. It will be seen that the top piston is larger in diameter than the bottom piston. The system is designed so that the valve spindle is in dynamic balance when the pressure above the top piston is approximately mid-way between the pressure up-stream of the main control valve, and the boiler pressure. To follow the operation of the regulator, let us assume that the system

is in dynamic balance, as drawn, and trace again the effect of an increase in steam draw-off. The eventual fall of water level will lower the float and the attached needle, thus increasing the size of orifice *B*. The resulting reduction in pressure-drop across orifice *B* will lower the pressure on the top piston, causing the main valve spindle to rise and increase the flow of feed water to the boiler. The valve will continue to rise until orifice *A* has approximately the same area as *B*, when the system will again be in equilibrium and the feed-water flow will match the increased steam-flow.

EXPERIENCE AT CALDER HALL

It will be appreciated, from Figs. 4 and 5, and the description of operation, that both the Robot and Steadiflow regulators operate on a similar principle. There is, however, a very important difference. By reference to Fig. 4 it will be seen that, in the case of the Robot, a small movement of the float makes an appreciable difference to the size of the needle-valve orifice. Thus a small variation in level makes a significant change in the pressure-drop across the orifice and the operating pressure above the top piston. Since the inertia of the moving parts is small compared with the operating forces, the Robot follows small changes of water level quickly and positively. It will be seen from Fig. 5 that the Steadiflow needles have a more gradual taper than the Robot needle. This is necessary because, in addition to varying the operating force on the top piston, the size of the orifice positions the control valve. This means that, for the same change in water level, the operating force available to the Steadiflow is smaller than to the Robot. Thus, in the case of the Steadiflow, some reduction of operating power has to be accepted for the advantage of eliminating the long feed lines to and from the steam drum.

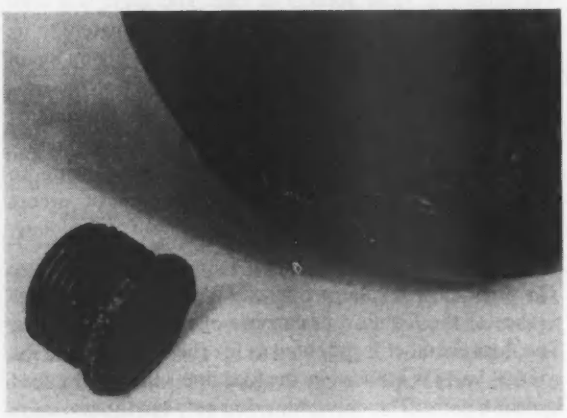


Fig. 6 (above) Failure of Monel float (boss welded to float)

Steadiflow feed-water regulator

Initially it was difficult to obtain reliable feed-regulation with these units, and much work was necessary before reasonable results were obtained. The Steadiflow tended to hunt, and one unit was so unstable that ultimately it had to be replaced by a Robot regulator to obtain steady operation: but the greatest inconvenience was due to float failures. In order to connect the float to the needle-actuating lever, a boss is welded to the Monel float (see Fig. 5). In a very short operating time the bosses would break away from the floats (see Fig. 6). Physical and metallurgical examination proved that the floats did not differ from those which had given satisfactory service for many years. Immediate action was taken to strengthen the assembly but this met with only partial success. It was some time before the intermittent high-pitched 'pinking' noises heard in the float chamber led to the speculation that the unusually low temperature of the Calder Hall feed-water (sometimes down to 76°F) might have something to do with the float failures. On one unit the bleed water was led away from the float chamber into the water space of the steam drum, and, immediately, the pinking noises ceased. Observations over a period showed no signs of deterioration of the float on this unit, and float failures ceased after this modification had been incorporated on all Steadiflows. There was no direct evidence of the cause of failure, but the condition of the metal at the point of fracture had the appearance associated with metal fatigue. One theory was that the small bleed of cold water entering the large mass of relatively hot water had set up shock waves (causing the pinking noises) which highly and intermittently stressed the float at the point of eventual failure.

A further disadvantage of the Steadiflow is that the cold

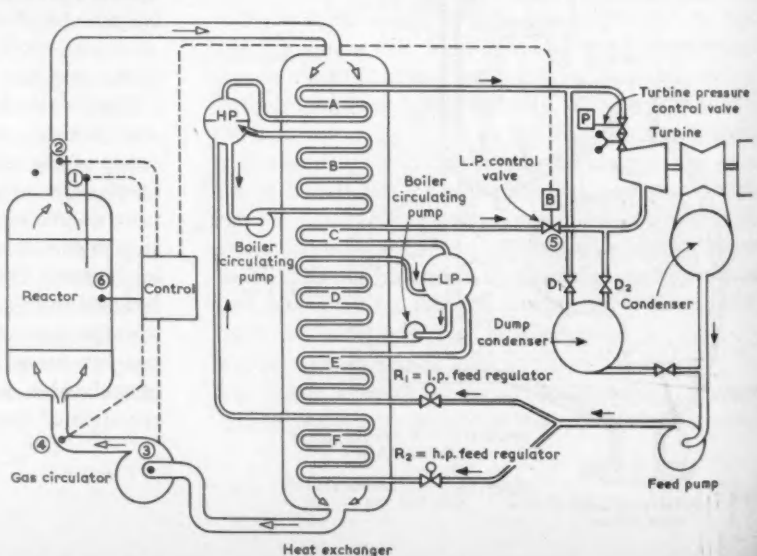


Fig. 7 (right) Simplified diagram of control system at Calder Hall: 1 Reactor control rods; 2 Reactor gas-outlet temperature; 3 Circulator speed control; 4 Reactor gas-inlet temperature; 5 L.P. steam pressure control; 6 Reactor power

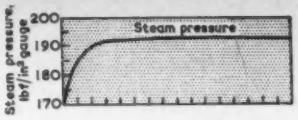
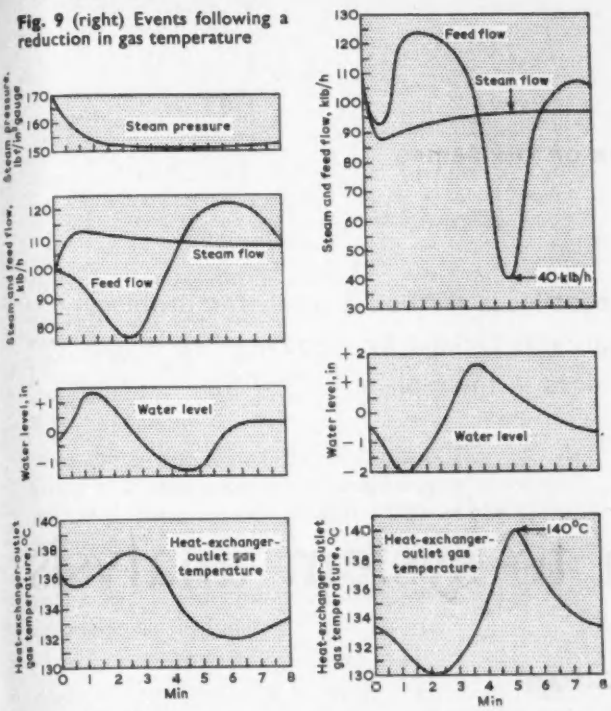


Fig. 8 (below) Events following a disturbance on the steam side

Fig. 9 (right) Events following a reduction in gas temperature



bleed-water has to be heated by mixing, irreversibly, with hot water in the drum.

Robot feed-water regulator

Initially, smooth control of the flow of feed water was impossible with this regulator. It tended to snap open or shut, giving on-off instead of continuous control. To overcome this difficulty it was necessary to modify the shape of the control-valve skirts to give a much more gradual valve-opening for a similar amount of valve travel. Like the Steadiflow, the Robot tended to hunt, but not so frequently. The initiation of hunting was traced to stickiness of the main control valve, due to either high spots on the mating surface or dirt in the boiler water. As the units were run in and the boiler water became cleaner, the hunting tendencies disappeared.

After the initial difficulties described, the Robot regulators settled down to give much more reliable service than the Steadiflows, within the limitations of single-element equipment, so much so that for the second half of Calder Hall Power Station, and the whole of Chapelcross Power Station, the high-pressure systems as well as the low-pressure circuits were fitted with Robot regulators. It is worth noting that, although the operation of Steadiflows has not been as satisfactory as that of the Robots, they are still operating at Calder A, and it has not been possible to justify the expense of changing them.

POINTS TO WATCH

When considering feed-water regulators for use with steam-raising units associated with atomic reactors, it may be useful to bear the following points in mind:

1 Feed systems should be designed to maintain a sufficient supply of water to ensure safe reactor-temperatures under all normal—and foreseeable abnormal—conditions of operation. The minimum requirement is that adequate water must be available at all times to dissipate fission-product heat even if the resulting steam, or hot water, should have to be discharged to waste.

2 A primary objective should be to reduce to an acceptable level the effect that automatic feed-water regulation may have on the reactor-inlet gas-temperature. In the ideal case this means that multi-element regulators will be required.

3 The regulators should be capable of controlling water-levels within very close limits to ensure the availability of the maximum amount of stored cooling capacity. NOTE:—When adjusting multi-element regulators to obtain the best results, as far as reactor-inlet gas-temperature is concerned, care should be taken to ensure that this is not achieved at the expense of close control of the water level and (*a*) consequent reduction in stored cooling capacity should the water-level settle too low, or (*b*) 'priming' should high water-level result.

4 Heat exchangers associated with the Calder Hall reactors, and civil reactors under construction, are numerous (four to eight per reactor) and are far apart. Because of this it is highly desirable that the feed regulators be capable of smooth control of feed, under all conditions, from zero to full load, to reduce to a minimum any necessity for hand control. This is of particular importance in the case of an emergency shut-down of the reactor, not only to eliminate hand control at such a time, but to minimize possible excursions of reactor-inlet gas-temperature. Regulators should shut-off positively at 'no-load' to prevent flooding during shut-down periods.

5 Regulator systems should be inherently stable with no tendency to hunt.

6 It is considered an advantage if:

(*a*) It is possible to operate the automatic feed-regulators manually from a remote position.

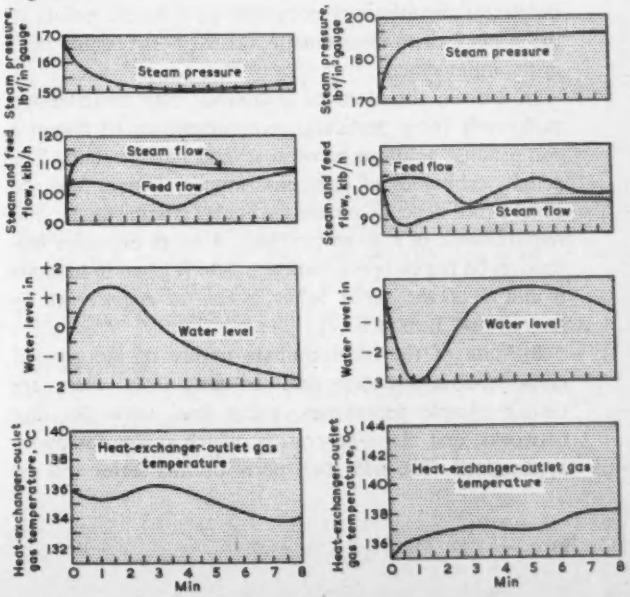
(*b*) The parts, or units, requiring most maintenance can be positioned in areas of low radio-activity.

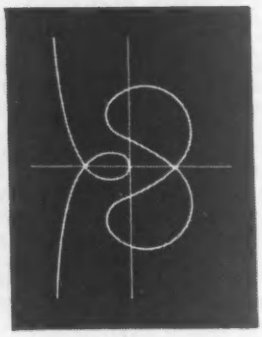
(*c*) The equipment is capable of operating without requiring power from an external source.

No doubt on future reactors improved methods of controlling the reactor inlet temperatures will be devised. However, it is highly probable that somewhere in the system the basic principles of the standard feed-regulator will be employed. In that case the above notes may be useful. *End*

Fig. 10 (left) Improvement on the case of Fig. 8 with two-element regulators

Fig. 11 (right) Improvement on the case of Fig. 9 with two-element regulators





NUMBER SIX OF THE SERIES

When the root-locus method is used, the problem of compensation is tackled by modifying the shape of the 180° lines in the p-plane

Pole-zero approach to system analysis

by **P. F. BLACKMAN**

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IN CONTROL ENGINEERING IT IS COMMON EXPERIENCE THAT the characteristics of certain components of a system—frequently the major components—are fixed and cannot be altered easily, and that the resulting performance of the system with these components is unsatisfactory. The manner in which the performance fails may be minor (such as a slight inadequacy in the transient response), or major. It may be desired to improve the band-width of the system so that higher-frequency components in the input signal may be followed, or to have very accurate following for low-frequency components. Alternatively, there may be a requirement to reduce the effect on the output of disturbances occurring at different points in the system, or to discriminate against noise components in the input signal.

In a given situation the endeavour may be to design exclusively for a particular requirement, or to obtain a compromise solution between several requirements. The actual techniques of compensation are legion, and the exact detail depends on the particular circumstances and requirements of a given problem. A more extensive discussion on the compensation problem is given in sections 6 and 7 of the series *What is control engineering* by Burrell and Lubbock (*1*).

In spite of the indeterminate nature of the general compensation situation outlined previously, there are certain simple techniques, using lead networks, lag networks, and tacho-generators, which suffice for many applications. The next two parts of this series will be concerned with these techniques and certain extensions.

In the root-locus method the 180° lines of the open-loop pattern completely define possible closed-loop pole positions as functions of gain, so that the system performance is controlled by the shape of these lines. When frequency-response analysis methods are used the general problem of compensation is tackled by modifying the system's frequency response, and possibly altering the gain. With the root-locus method, the problem is tackled by modifying the shape of the 180° lines in the p-plane.

Lead network

For a system with a forward path characterized by an integration and two time-constants, the open-loop transfer is

$$\theta_0(p)/E(p) = K_1/p(1 + p\tau_1)(1 + p\tau_2)$$

where K_1 is a gain constant, and the 180° lines have the general form of Fig. 1a, the forward line crossing the axis at $\omega = \pm 1/\sqrt{\tau_1\tau_2}$*. If a particular damping ratio ζ_1 is used as the closed-loop design criterion, the closed-loop poles will be located at p_1, $\bar{p}_1$, giving a closed-loop frequency-response as in Fig. 1b, with a band-width of about ω_1 radians, and dominant modes $\exp(-\alpha_1 \pm j\omega_1)t$.

It may be required to move the dominant poles along the ζ_1 line in order to obtain a faster response†, and this can be achieved only if the 180° line can be made to

* See Fig. 15 in part 5B (May 1961). † See Fig. 1 in part 5A (April 1961).

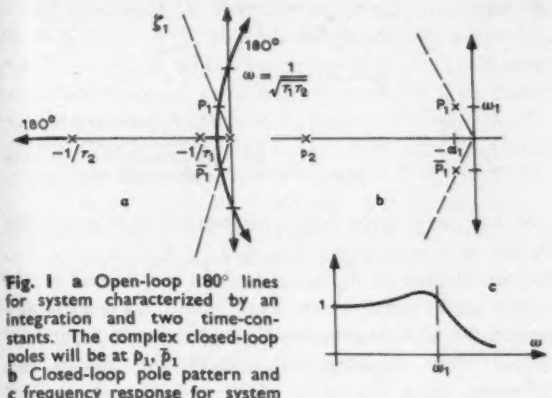

Fig. 1 **a** Open-loop 180° lines for system characterized by an integration and two time-constants. The complex closed-loop poles will be at p_1, $\bar{p}_1$
b Closed-loop pole pattern and **c** frequency response for system of **a**

cross the ζ_1 line at a higher frequency. This may be arranged if some additional elements can be introduced to give a phase advance in the vicinity of the ζ_1 line beyond p_1.

One possible method is to introduce into the forward path a *lead* or *phase advance* network, as shown in Fig. 2a, which has the transfer

$$T(p) = K_0(1 + p\tau)/(1 + pK_0\tau)$$

where $\tau = C_1R_1$, and $K_0 = R_2/R_1 + R_2$, (<1), corresponds to the d.c. transfer. The network is characterized by a pole and zero on the negative real axis, the ratio K_0 between the pair corresponding with the d.c. transfer. The network provides a phase advance ϕ at any point in the upper half-plane, the constant-phase lines being circles passing through the pole and zero and making an angle ϕ between the tangent and the real axis. The effect of placing this network in the forward path is to modify the forward 180° lines to the general form of Fig. 3, crossing the ζ_1 line at p_2, where the additional lag due to the uncompensated system, and the advance due to the network ϕ_2, are equal. There are also two 180° lines on the negative real axis.

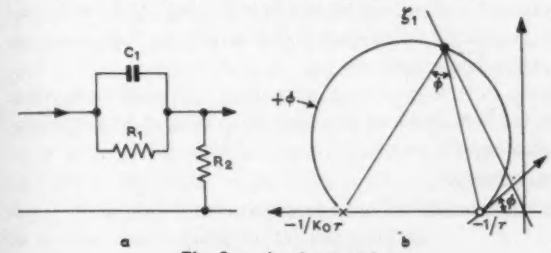

Fig. 2 **a** Lead network
b Constant-phase circle $(+\phi)$ for the lead network

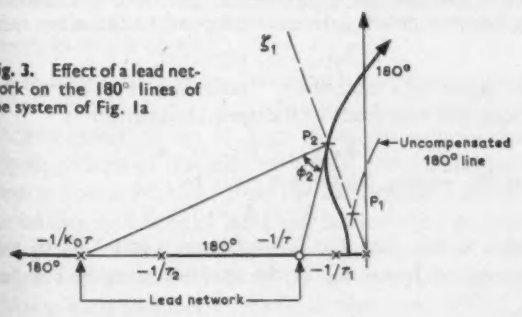

Fig. 3. Effect of a lead network on the 180° lines of the system of Fig. 1a

If it is required that the dominant closed-loop poles be located at a chosen point p_k where the system angle is $-(180° + \phi_k)$, there is an infinity of combinations of K_0 and τ which would produce a constant-phase circle of $+\phi_k$ passing through p_k, and a few of these are shown in Fig. 4a. The ratio between the pole and zero, which

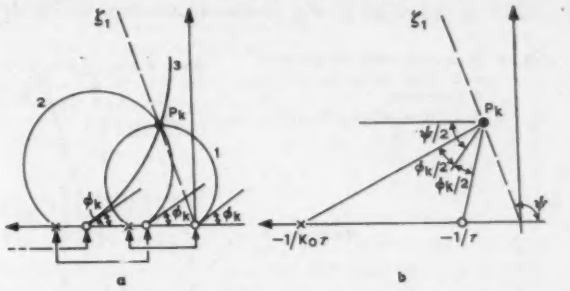

Fig. 4 **a** Various pole-zero locations to give a lead of $+\phi_k$ at p_k
b Construction to locate pole and zero to yield minimum attenuation (K_0)

gives K_0 the d.c. transfer, varies from zero for circle 1 to a finite value for circle 2, and approaches zero again for circle 3, in which case the pole is far removed along the negative real axis. Since the loss K_0 must be replaced by additional gain in the forward path, and yet more gain will be required since the final poles are to be further out in the plane, it is desirable to choose the pole-zero location approximating to the maximum value of K_0. The construction (*2*) outlined in Fig. 4b gives the locations for the maximum value of K_0, the steps in the construction being:

a **draw a horizontal line through p_k, the required closed-loop pole location.**
b **draw a line at $\phi/2$ below this line, and draw lines $\pm\phi_k/2$ to intersect the negative real axis.**
c **the compensation pole and zero are located at the intersection points on the negative real axis.**

The complete closed-loop pattern will be as in Fig. 5,

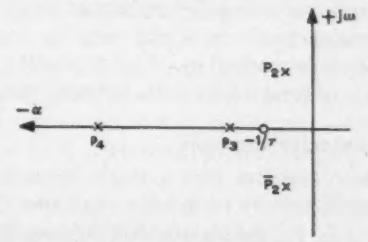

Fig. 5 Closed-loop pattern for system of Fig. 1a, with lead-network compensation

the zero in the lead network surviving into the final pattern. There are two poles on the negative real axis, p_3 located on the 180° line between the lead zero at $-1/\tau$ and the system pole at $-1/\tau_2$, and p_4 on the 180° line passing from the lead pole at $-1/K_0\tau$ to infinity.

An example

As an example of the lead network consider a system with the forward path transfer

$$\theta_0(p)/E(p) = K_1/p(p + 1)(0{\cdot}2p + 1)$$

where K_1 is a gain constant. The 180° lines are shown in Fig. 6a, the forward lines crossing the axis at $\omega = \pm 2{\cdot}24$*, and if $\zeta = 0{\cdot}4$ is used as a design criterion the closed-loop poles are located at $p = -0{\cdot}35 \pm j0{\cdot}9$, giving a closed-loop band-width of about one radian a second, and requiring a gain K_1 of about 1. If it is required to obtain closed-loop poles on the $\zeta = 0{\cdot}4$ line at (say) $p = -1 \pm j2{\cdot}5$, the phase advance required is 54°, since the uncompensated system has a phase angle of −234° at this point. In Fig. 6b the construction of Fig. 4b

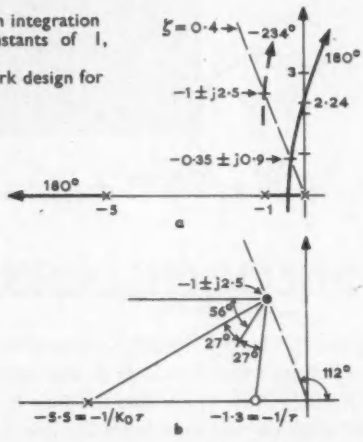

Fig. 6 a System with integration and time constants of 1, 0·2 seconds
b Lead-network design for system in a

is applied to the present example, and the pole and zero are found to be located at $p = -5{\cdot}5$, $-1{\cdot}3$, respectively, yielding $K_0 = 1{\cdot}3/5{\cdot}5 \simeq 0{\cdot}235$

The transfer of the required lead network is,

$$0{\cdot}235(1 + 0{\cdot}77p)(1 + 0{\cdot}18p)$$

and the closed-loop poles are determined by,

$$\frac{0{\cdot}235K_1(1 + 0{\cdot}77p)}{p(1 + p)(1 + 0{\cdot}2p)(1 + 0{\cdot}18p)} = -1$$

or

$$\frac{(p + 1{\cdot}3)}{p(p + 1)(p + 5)(p + 5{\cdot}5)} = -0{\cdot}2/K_1$$

and evaluating this pattern at $p = -1 + j2{\cdot}5$ by direct measurement on a plot gives the value 0·0153, so that K_1 is determined by, $K_1 = 0{\cdot}2/0{\cdot}0153 \simeq 13$
thereby establishing the forward path gain.

Velocity constant

For a system with a single integration in the forward path, together with additional poles and zeros $\tau_1 \ldots$, $\tau_a \ldots$, the transfer has the general form,

$$\frac{\theta_0}{E}(p) = \frac{K_1(1 + p\tau_a) \ldots .}{p(1 + p\tau_1) \ldots .}$$

and the output shaft velocity

$$\frac{d\theta_0(t)}{dt} \text{ or } p\theta_0(p) \text{ or } \dot{\theta}_0(p)$$

is given by $\dfrac{\dot{\theta}_0}{E}(p) = \dfrac{K_1(1 + p\tau_a) \ldots .}{(1 + p\tau_1) \ldots .}$

* $\omega = 1/\sqrt{\tau_1\tau_a}$.

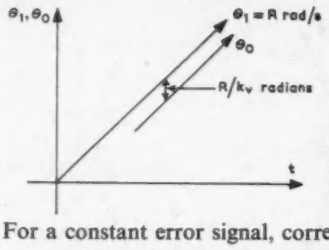

Fig. 7 Input (θ_1) and output (θ_0) angles under steady-state conditions, with input shaft rotated at R rad/s

For a constant error signal, corresponding to $p \to 0$, the output shaft velocity is given by $\dot{\theta}_0 = K_1E$
the dimensions of K_1 being (*radians per second at the output shaft*)/*radian error*. The 'gain' K_1 is normally termed the *velocity constant* K_v, and controls the input–output shaft misalignment (error) for *steady-state* following, since the value of K_v indicates the steady error that must exist in order to drive the output shaft at the same speed as the input shaft. Fig. 7 shows the input and output shaft angles where an input of R radians per second produces a steady following error of R/K_v radians, and hence higher forward path 'gain' gives reduced following error.

When the system's closed-loop poles are being investigated, the open-loop relation

$$\frac{(p + 1/\tau_a) \ldots .}{p(p + 1/\tau_1) \ldots .} = -\left(\frac{\tau_1 \ldots}{K_v\tau_a \ldots}\right)$$

is considered and values of p found to satisfy this relation. Hence, at the closed-loop pole locations p_k, the open-loop pattern has magnitude $(\tau_1 \ldots .)/(K_v\tau_a \ldots)$
If the pole at the origin is omitted, the magnitude given by the *remainder* of the open-loop pattern at the origin (obtained for $p \to 0$) is $(\tau_1 \ldots .)/(\tau_a \ldots .)$
thus the ratio

$$\frac{\text{(magnitude of open-loop pattern at origin, } \textit{omitting} \text{ pole at origin)}}{\text{(magnitude of open-loop pattern at closed-loop pole location } p_k)} = K_v$$

permitting the velocity constant of a system to be obtained directly from the open-loop pattern when the closed-loop pole locations have been determined. This may easily be checked on a scaled diagram of Fig. 1a, to yield a velocity constant of about 1. For the case when a lead network is added the forward path transfer is similar in form

$$\frac{K_1K_0(1 + p\tau)(1 + p\tau_a) \ldots .}{p(1 + pK_0\tau)(1 + p\tau_1) \ldots .}$$

except that the 'gain' term now becomes K_0K_1, and the closed-loop pole locations correspond to the magnitude

$$(K_1\tau_1 \ldots .)/(\tau_a \ldots .)$$

the factor $K_0\tau$ cancelling. Neglecting the pole at the origin, the magnitude of the open-loop pattern is

$$(K_0\tau_1 \ldots .)/(\tau_a \ldots .)$$

and the velocity constant is given by

$$K_v = K_0K_1$$

which is less than the forward path 'gain' K_1 by the attenuation factor K_0. In the example given in Fig. 6a, $K_v \simeq 2{\cdot}6$.

If it is desired to increase the velocity constant, a direct increase in K_1 will not be satisfactory since the closed-loop poles will advance towards the imaginary axis. If the poles are to remain substantially in the same location, the requirement is to introduce an additional pattern which gives a value at the origin which is much larger than the value in the vicinity of p_k, and also introduces no significant phase lag so that the position of the closed-loop poles is not altered. An approximation to these properties is provided by the *lag* network.

Lag network

The lag network of Fig. 8a provides unity transfer at d.c., and an attenuation at high frequencies, the transfer being $(1 + p\tau)/(1 + p\tau/K_\infty)$
where $\tau = C_1R_1$, and $K_\infty = R_1/R_1 + R_2$ (<1) corresponds to the limiting high-frequency value of the transfer. The transfer is characterized by a pole and zero on the negative real axis, the ratio between the two being K_∞. Since the pole is closer to the origin it is possible in principle to obtain a ratio, with a limiting value of K_∞, between the pattern values at the origin and out in the plane. Also there is always some phase lag ϕ in the plane, the constant-phase lines being circles as for the lead network.

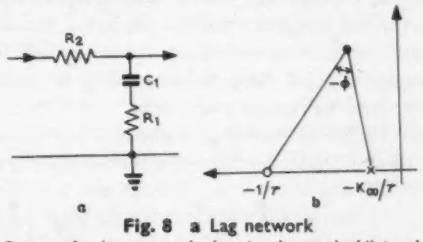

Fig. 8 a Lag network
b Pattern for lag network showing lag angle (ϕ) in plane

In using this network two general situations may be considered:

a **The pattern may be located with the pole in front of the system pole at $-1/\tau_1$ and the zero beyond as in Fig. 9a. The 180° line from the leading pair of poles will cross the damping line at a very low frequency, and be generally deflected towards the imaginary axis due to the phase lag. This shows that an adequately damped closed-loop pole can only be obtained with very low frequency p_1, and thus the ratio between pattern values at the origin and p_1 will be nearly unity giving a poor velocity constant.**

b **The pattern may be located closer to the origin, while still maintaining the required value of K_∞. This results in a reduction of the phase lag in the plane, giving a 180° line of the general form of Fig. 9b, where the line may approach or cross and re-cross the damping line at a low frequency, but finally crosses at a higher frequency p_2. In this case there is a large ratio, approaching K_∞, between the pattern values at the origin and p_2, yielding an improved velocity constant.**

The arrangement in Fig. 9b might be satisfactory, and, if the compensation is moved closer to the origin, the complex poles shown in Fig. 9c would more nearly approach those of the uncompensated system. However, there is also a 180° line from the compensation zero to the leading system pole, on which there will be a closed-loop pole p_3, which could be relatively close to the origin and give rise to a slowly decaying exponential component yielding an unsatisfactory transient response.

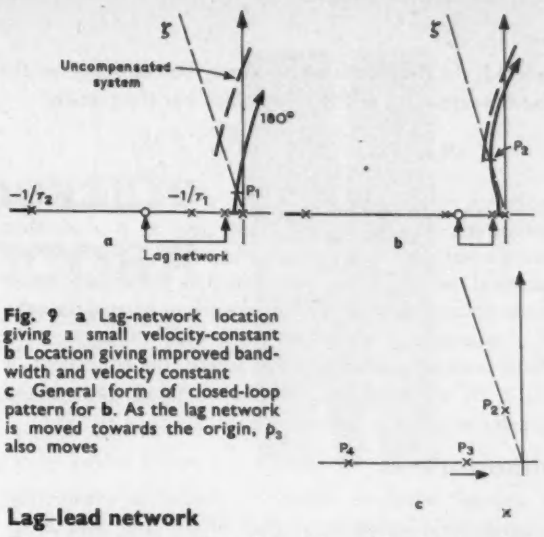

Fig. 9 a Lag-network location giving a small velocity-constant
b Location giving improved band-width and velocity constant
c General form of closed-loop pattern for b. As the lag network is moved towards the origin, p_3 also moves

Lag–lead network

The general properties of the lag and lead networks are in fact complementary, and the two may be used together to obtain the advantage of the lag network to give a high value of K_v, and the lead network to deflect the 180° lines away from the imaginary axis to give an adequate band-width. For the system already considered, with the forward path transfer $\theta_0(p)/E(p) = K_1/p(1 + p)(1 + 0{\cdot}2p)$ a lag network with parameters $K_\infty = 0{\cdot}1$, $\tau = 1{\cdot}0$, might be chosen which gives a 180° line as in Fig. 10a,

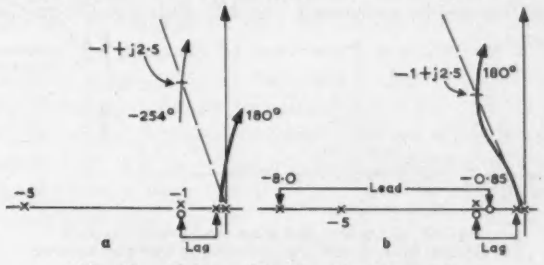

Fig. 10 a System of Fig. 1a with lag network
b Lead network added to system in a

which alone would yield a poor value of K_v, with very-low-frequency dominant poles. If it is proposed to move the poles to the previous values of $p = -1 + j2{\cdot}5$, the phase angle at this point is found to be $-254°$, so that an advance of 74° will be required. If a lead network is designed using the construction of Fig. 4b, the zero and pole are located at $-0{\cdot}85$, $-8{\cdot}0$ respectively, giving the general form of 180° line as in Fig. 10b. The velocity constant K_v may be found to be about 20, representing a considerable improvement over the previous results.

Although two separate networks have been con-

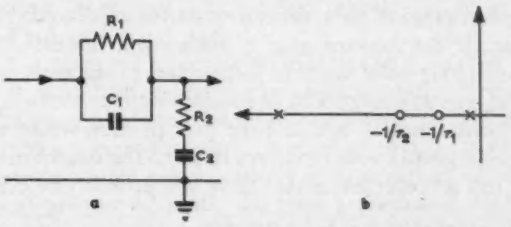

Fig. 11 a Lag–lead network b Pole-zero pattern

sidered, the properties of both may be combined in the *lag–lead* network of Fig. 11a, which has the transfer

$$T(p) = \frac{(1 + p\tau_1)(1 + p\tau_2)}{p^2\tau_1\tau_2 + p(\tau_1 + \tau_2 + \tau_{12}) + 1}$$

where $\tau_1 = C_1R_1$, $\tau_2 = C_2R_2$, $\tau_{12} = R_1C_2$. The transfer magnitude is unity at d.c., and also as $p \to \infty$, thus being equivalent to lag and lead networks in series with identical values of K_∞, K_0, which is sufficiently exact in the present example for the network to be used directly. If a resistance is placed in series with the input, or a shunt resistance placed on the output, the equivalent of $K_\infty < K_0$ or $K_0 < K_\infty$ may be obtained, though the transfer expression becomes more complicated (*3*).

Additional ideas

A concept which is sometimes useful in considering compensation networks is that of *lag* and *lead areas* corresponding with the relevant phase angles. For example the lag–lead network has a circular 0° locus*, the inside of the circle being a lag area and the outside a lead area for the upper half-plane as in Fig. 12a, and *vice versa* in the lower half. Any 180° line of an uncompensated system lying in a lag area in the upper half-plane will be deflected towards the imaginary axis, while in the lead area it will be deflected in the opposite direction. Also the point where the 180° line crosses the 0° line will be unchanged. Fig. 12b illustrates the general effect.

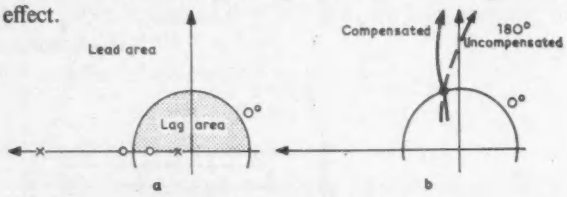

Fig. 12 a Lag and lead areas for lag–lead network
b General form of 180° line deflexion in lead and lag areas

Various bridge networks†, such as that shown in Fig. 13a, which has the transfer

$$T(p) = \frac{(p\tau)^2 + 2p\tau + \beta}{(p\tau)^2 + p\tau(2 + \beta) + \beta}$$

where $\tau = C_1R_1$, $\beta = C_1/C_2$, have complex zeros and give rise to semi-circular lag areas. With such a network a 180° line might be arranged to terminate on the complex zero giving the general pattern of Fig. 14a, in which the line might pass into the right half-plane, but finally terminates on the zero located to the left of a given damping line. Such a system could exhibit *conditional instability*, or else reduced damping over a certain range of gain, depending on the exact configuration. If the forward gain is made high, however, the closed-loop poles might be forced close to the zeros, and adequate damping could be ensured together with a high velocity-constant, and also the pole position would not change greatly with variations of gain. The disadvantage of this arrangement is that there will probably be other

* See page 94, *Circular loci*, Part 5B (May 1961).
† See also Fig. 10, Part 3 (January 1961).

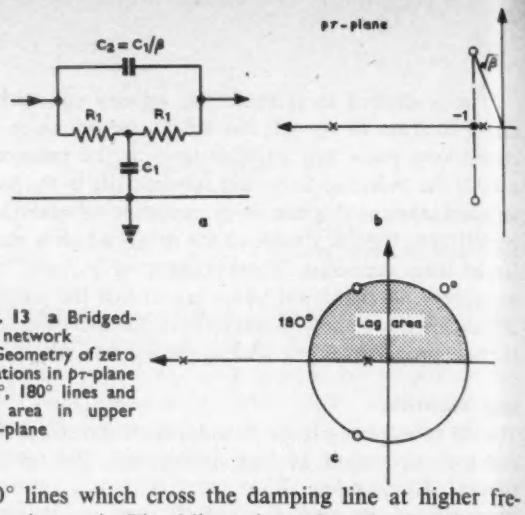

Fig. 13 a Bridged-tee network
b Geometry of zero locations in $p\tau$-plane
c 0°, 180° lines and lag area in upper half-plane

180° lines which cross the damping line at higher frequencies, as in Fig. 14b, and a value of gain adequate to place the low frequency poles to the left of the damping line may result in unsatisfactory positioning for the high-frequency poles. Also, the possibility of conditional instability may be viewed with alarm.

In the situation mentioned above, the lag area is centred on the origin, but an entire pattern can be shifted

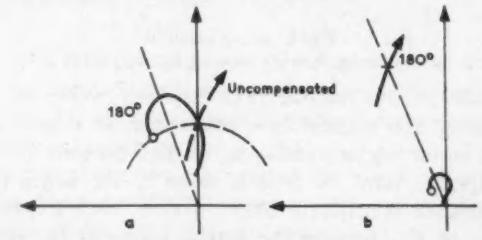

Fig. 14 a 180° line terminating on a complex zero, giving conditional instability b Additional 180° line crossing damping line at higher frequency

to the left if the capacitors in the network are shunted with resistors of such value that all time constants of the parallel combinations are the same. If the network of Fig. 13a is modified as in Fig. 15a, the entire pattern

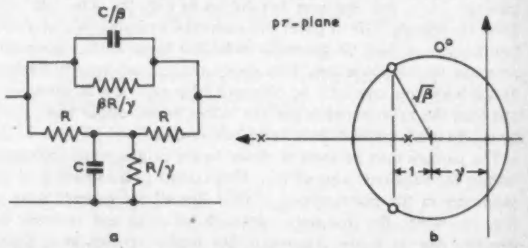

Fig. 15 a Modification of tee-network of Fig. 13a to shift pattern γ units in the $p\tau$-plane b Shifted pattern

will be shifted γ units in the $p\tau$-plane,* as in Fig. 15b, which may permit the damping to be increased adequately for the full range of gain values.

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   Del Toro, V., & Parker, S. R.: 'Principles of Control Systems Engineering', p. 461.
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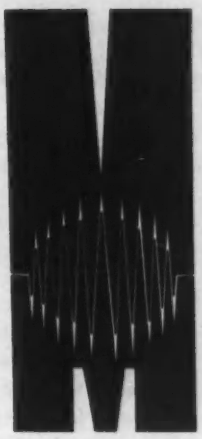
* This procedure is a form of *frequency transformation*. Frequency transformations are discussed in several of the general references at the end of Part 3, January, 1961.

The measure of MESUCORA

by **H. G. BASS** M.A.
Deputy Editor, Control

Some impressions of last month's international instrument and automation exhibition—the first of its kind to be held in France



THE COMBINED EFFECTS OF STRIKES, MILITARY obsequies, and the threat of civil war in the period leading up to the 9 May left Paris in such a state of confusion that it was remarkable that the exhibition opened at all. In spite of this unhappy combination of circumstances, which must have been unusual even in France, the opening took place as scheduled. The anxiety which preceded the opening had been greater than usual, but by Wednesday 10 May an atmosphere of calm reigned in the C.N.I.T. hall, and there was little outward sign that circumstances had been other than normal. Behind the scenes the situation was slightly less happy, as postal delays, coupled with suspicious customs departments, had held up much of the incoming printed matter. One major foreign exhibitor received none of his technical literature, and supplies of some journals — including *Control*—were also delayed.

The C.N.I.T. hall—a large, three-sided, curved-roofed structure with glass walls—dominates the otherwise unremarkable suburb of Puteaux. It is surrounded by ample parking space, and in this, as in several other respects, any comparison with British exhibition halls would be to the latters' disadvantage. The C.N.I.T. hall does have some drawbacks. Though easy to find, it is not easy to get to, unless you have your own transport. The Paris Metro seems less willing than its London counterpart to spread its tentacles into the suburbs. A further disadvantage appears to be the lack of suitable conference accommodation. The conference accompanying Mesucora was held some distance from the hall. This, and the lack of adequate advance details of the conference program, caused it to be poorly supported, though it appears to have been full of good things.

The exhibition, too, was probably not as well supported by either exhibitors or visitors as its organizers had originally hoped, in spite of intensive publicity. Though it lacked the urgency of Interkama, it lacked also the confusion of the I.E.A., and was consequently probably more pleasant to visit than either. The disturbances mentioned above may have contributed to the lack of support, but a more important cause was probably the cautious attitude of many potential or actual exhibitors. One felt that quite a lot of the exhibitors had only come along to take a look, so that they would know what to do next time. Many foreign firms were showing only a small portion of their wares, usually on local agents' stands. The actual number of firms represented in some way was about 600, but the number of stands was around 450. Of the non-French organizations that seemed to give it full treatment, Elliott's, Siemens, Hartmann and Braun, and Honeywell stood out. The Elliott empire lost some of its potential impact by being subdivided into its component parts, in contrast to the large German firms, whose 'open plan' layout struck a confident note.

No standard signal

Opinions on the optimum range for electrical transmission signals seem to grow more varied, rather than less. In general, European firms seem to prefer to work from a true zero, whereas Americans use a signal of a few milliamps (usually 1/5 of the maximum signal) to represent the zero of the measured variable. The American system has the possible advantage that it is more readily adaptable to two-wire systems—as in the Honeywell Teloset equipment. This system uses a 4–20mA signal range, the residual 4 mA signal providing power for the oscillator in the transmitter. Meci, a firm formerly strongly connected with Leeds and Northrup, showed equipment which could operate on either a 0–4 mA or 1–5 mA range.

You need not, of course, have a standard signal at all —at least between measuring element and controller. This reversal of accepted fashion was apparent in a new Siemens electropneumatic controller, which receives measured-value signals directly from a variety of electrical primary elements, and gives a pneumatic output. On the input side, an electric circuit in the form of a

plug-in block compares the input signal with the desired value, and produces a mechanical force representing the deviation. This force forms the input to the pneumatic part of the controller. A number of plug-in circuits is made, to suit different measuring elements. The controller mechanism employs two pneumatic amplifying stages and has very high gain. By way of innovation, there are no pipes in the controller, all pneumatic connexions being cast in an aluminium alloy base-plate. The primary balance-detecting device takes the form of a vane moving laterally between two nozzles, instead of the conventional flapper-nozzle which has become almost standard on pneumatic controllers. It is interesting to note that the same type of position detector is used in a new Bristol two-term controller which was being shown by Elliott's. This inexpensive instrument is to be produced in addition to the standard Bristol three-term controller. It is intended primarily for those applications where a continuous controller is required at an 'on–off' price.

A significant feature of several new controllers at the show was the absence of an intermediate position between the 'auto' and 'manual' positions on the auto/manual switch. The German firms seemed to take this very much for granted, but it appears that it can only be done successfully when integral action is used.

Those who take the attitude that pneumatic control systems are doomed might do well to take a look at the activities of the larger German firms. The Siemens controller mentioned above, which seems to show a determination to retain pneumatics at least on the output side, is the second radically new pneumatic controller to come out of Germany during the last year. The other, the much-publicized Eckhardt 'cross-bellows' controller* which appeared at Interkama, was not shown, Eckhardt having no stand at Mesucora.

Electric actuation

The position of 'all-electric' schemes may be strengthened by the new Adar electrically-operated control valve.† Basically, this valve operates on pneumatic principles, using a sealed inert-gas system requiring only an electric supply. Adar were apparently so concerned for the welfare of their prototype that they thought it necessary to conceal it in the inner sanctum of their stand, where it must have passed unnoticed by the more casual visitor. Any suspicion that this actuation system might be just another gimmick was quickly dispelled on making its acquaintance. It looked well-engineered, and was very sensitive to input signal changes. Initial production will be for valves in the 2–8 in range, the actuators having a maximum thrust of 1000 kgf and a stroke of 66 mm. The makers claim that the cost will be about half that of the equivalent electrohydraulic valve, and that the closed-circuit gas system should work for three years without servicing. Such parts of the positioning mechanism as may require attention (e.g. for calibration adjustment) are accessible without breaking into the sealed chamber.

These control valves have apparently been under test by Shell, and it has also been whispered (though, needless to say, not by I.C.I.) that I.C.I. are taking an interest in them.

Power

A great deal of space on central stands was occupied by public concerns—particularly by Electricité de France (E.D.F.) and nuclear research centres. Both electrical and nuclear authorities seem very active in instrument development. This was perhaps to be expected in the nuclear field, where development may depend on the availability of reactors, but came as something of a surprise in the case of the electrical supply industry. E.D.F., however, has certain particular problems of its own, especially in connexion with the use of tide-power for the generation of electricity, and much of the equipment on their stand had been developed for this field.

On the subject of computer control, the situation did not seem very clear, possibly because of linguistic misunderstandings, but it looks as though E.D.F. has so far used computers for data-logging functions only.

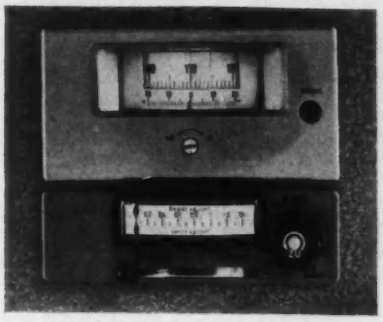
Data processing

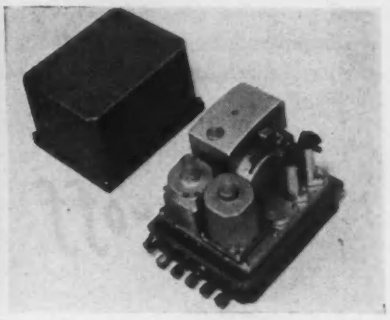
There appears to be more demand in France than in this country for data transmission over relatively long distances, there being several firms specializing in this type of equipment. Pulse-modulated voice-frequency transmission seems to be much favoured. S.A.C.M. also showed a new frequency-modulated system for binary signals, claimed to reduce the distortion normally caused by amplitude discontinuities when changing from one frequency to the other. In this system, the two frequencies are synchronized with the binary signal, so that the change-over always takes place at maximum amplitude on the same phase. This involves the use of frequencies which are related to each other, and to the frequency of the binary signal, in an arithmetically simple fashion.

There were more signs of activity in indigenous French computers than expected. Those shown at the exhibition were essentially for scientific purposes. The leading French firms in this field appeared to be Labinal Electronique and S.E.A., the latter firm having a number of other interests in the automation field. Labinal, a firm whose activities have previously been concerned mainly with precision mechanical equipment, showed their Delta 600 differential analyser. This is described as an 'industrial' machine for solving problems involving partial differential equations, which would be unduly complex if solved by the conventional method of finite differences. S.E.A. were demonstrating a small general-purpose digital computer—the C.A.B. 500—intended mainly for research establishments. They have some intention of trying to sell this computer in the U.K. It is claimed that its price here will compare

* See *Control*, Dec. 1960, p. 121.
† Described in last month's *Control*, page 113.

Electric inputs
Left: this prototype Adar control valve has pneumatic operating characteristics but requires only electric inputs; it uses a closed-circuit inert-gas system with its own compressor. Below: the new Siemens controller, which gives a pneumatic output for an electric input. Note (left) that no balance position is used between the 'auto' and 'manual' positions. The controller mechanism (right) is pneumatic, all internal connexions being cast into a light-alloy base-plate.





favourably with that of British computers in the same class.

At least one French firm, Alsthom (associated with American General Electric), is well established in solid-state switching. A panel of Logistor units, destined for an automatic screw-down installation in a steelworks, was on show. Alsthom claim to have supplied twelve sets of equipment of this kind to the French steel industry. The input is from a simple and robust slotted-disk photo-electric unit. A control unit, designed to give either fully-automatic or semi-automatic operation, also carried a digital display showing the required thickness and the instantaneous error.

Recorders

The exhibition abounded with recorders of all sizes, among them several miniatures, of which a surprising number were direct-deflexion instruments. Amongst the full-size instruments, the new Merlin and Gerin Hexomatic six-point recorder is unusual in that it employs six independent slide-wires, using a common servo-balancing system. Each slide-wire is wound on a straight tubular former, and the sliding contacts are integral with the six pen-carriages. The slide-wires are mounted in a 'squirrel cage' structure, which rotates about a central axis behind the chart mechanism. Printing is achieved by moving the chart back on to each pen at the appropriate time in the operating cycle. A disadvantage of the system would appear to be that the record is not visible immediately after printing, as this is carried out on the back surface of the upper chart roller. An advantage may be that special characteristics can be built into individual slide-wires relatively easily.

Other novelties in this field included the frontal pull-out controls for sensitivity and chart-speed on the new A.O.I.P. six-point miniature recorder, and the Meci self-effacing records. This latter system, which may be fitted to both the full-size circular-chart recorders and miniature strip-chart instruments made by Meci, effaces the record as soon as it leaves the visible portion of the 'chart'. The ink records, which on both demonstration instruments were very well defined, are made on a glass surface, and are washed off in a liquid bath on leaving the normally visible area. Meci evidently feel there is a market for instruments giving only a temporary record, with consequent savings in charts and labour.

Low-speed motor

The much-discussed Stéromoteur low-speed a.c. motor* was being demonstrated by S.F.A.I.R.E. Only one size of motor is at present being manufactured, having a nominal torque of 400 ozf in, and available with speeds of rotation between 10 and 100 rev/min. The 'rollers' for this size of motor are rubber covered, and run in an Araldite track. A certain amount of heat is generated, and vibration is apparent on the motor body, but this appears to be damped out successfully by the coupling used on the output shaft. The two great advantages of this form of motor appear to be cheapness and low inertia. The makers consider that, for low-speed applications, the price will be about half that of the equivalent conventional motor and gearing. Because of the low inertia, the motors may be stopped rapidly without distress. A motorized valve, driven by a Stéromoteur, was demonstrated. Complete closure was ensured by driving the valve on to its seating, and cutting out the motor after a further time delay. Apart from a somewhat noisy vibration during the stalled period, the motor accepted this treatment cheerfully. This seems to be the sort of application for which the existing Stéromoteur is ideally suited. Smaller versions are planned, in which the central portion will be the stator, and an outer ring will roll round it. The rolling surfaces in this case will be iron on Araldite. One feels that this might be a happier arrangement for long-term continuous running than the existing system, though the makers anticipate a trouble-free life of about a year for the present model, after which replacement of the rubber surfaces will be necessary.

* Described in last month's *Control*, page 112.

Pick-off

by 'UNCONTROLLED'

WHY DO THE HOT-GOSPELLERS of automation still preach about 'feedback' as if it were the divine essence of the matter? As a simple techno-literary hack I am bewildered by the whole thing. If I remember my lessons correctly, you can draw dependence diagrams almost any way you like. Since you can so whimsically convert the equations of a system into a signal-flow chart with or without feedback (or feedforward), is not the concept of feedback (or feedforward) proved to be merely a thing of the mind—most useful for working things out on paper but not *necessarily* corresponding one-to-one with any physical link in the hardware?

THE RECEIVED DOCTRINE so far has been that control theory is all one, and that the principles of servo-mechanisms are indistinguishable from those underlying process control. I have recently been getting the impression that this may not remain received doctrine for much longer—at least in its present form—and that both will turn out to be special cases of something bigger. The time constants involved in the two fields are so very different, and the equations needed to specify component dynamics are so much more numerous in process work, that servo-methods just don't seem to produce any worth-while results. Most chemical processes are after all inherently stable, and that changes the emphasis quite a lot. The aircraft approach, involving elaborate simulator studies, has been tried pretty thoroughly by a few people working on process control problems, but I have heard of very few cases where the cost of the research has been justified. The biggest benefits usually seem to come in understanding of the processes themselves, leading to better operation but not necessarily to a call for automatic control.

TO ENGINEERS, scientists and mathematicians, symbols are mostly letters taken from the available alphabets, but when an artist produces a 'symbol' he tries to associate ideas in quite a different way. The modern artist's method is sometimes too inwardly personal to excite resonance in his audience, and philistinism becomes the natural response. I confess that this tended to be my own (defensive) reaction to the ten designs put up for a sculpture at Mullard's new labs at Salfords, when I saw them at a press showing a while ago. Sir Kenneth Clark presented a cheque for 500 guineas to the winner, Mr Keith Godwin, for the design illustrated in my photograph.

The finished job is to be 6ft high, on a slab 2 ft square by 18 in high. The sculptor's own explanation of his symbol is that it 'evolved as a simple statement that opposite poles attract and like poles repel'. For my own part, I find a lines-of-force diagram a much more evocative statement to this effect, but I agree that a trough of iron filings would not look so well in the forecourt of a building. Of course, Sir Kenneth Clark was quite right when he said at the presentation that modern industrial patronage sets the most difficult problem of all for artists — symbolization of abstract entities like force, energy and power. In an age when patrons are hard to come by, however, the community must be more grateful than ever to those enlightened firms that provide what patronage there is.

IT IS ALWAYS a pleasure for me to record progress. In *Pick-off* for October 1958 I drew on Dr Wilkes' presidential address to the B.C.S. for the latest news of π, which at that time was known to 10,000 places. Now I hear that Mr N. D. Robinson of E.M.I. has used his firm's computer to push the frontiers of knowledge to 10,880 places. The machine, an Emidec 1100, took thirteen hours of computing time to do the 35 million sums that were needed. Actually, the exercise was undertaken to test the reliability of the computer, and it seems to have done well enough. E.M.I. have worked out (but apparently not on an Emidec) that if a fifteen-year-old boy were started on the job he would have to slog away until he was eighty to reach the 10,880th place. I don't think he'd keep his senses for as long as that, which may mean that computers are more reliable than human beings, or it may not.

ONE OF MY COLLEAGUES recently received a letter asking him to provide definitions of *control engineering* and *control systems*. Here is an extract from his reply: 'I should say that *control engineering* is the study, analysis, design, manufacture, installation, maintenance and operation of control systems. A *control system* (and here I am leaning on British Standard No. 1523:1954) is an arrangement of elements (such as instruments, amplifiers, actuators and human operators) which are interconnected to act and interact in such a way as to control certain conditions of a body, process, or machine'. More recently still I heard of a works-canteen discussion on how to define a *control engineer*. According to my informant there were several attempts to do this, some of them along the lines of my colleague's effort, but the contribution I liked best was: 'A *control engineer* is an engineer who reads *Control*'. Simple, really.

A monthly review — under basic headings — of the latest control engineering developments for all industries; especially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to ANALYSIS

Null-balance differential radiation detector

ANTHONY CLARK, Distillers Company Ltd

A new type of radiation detector* has been developed by the Instrumentation Section of the Distillers Company Ltd. It has many possible applications, but was designed primarily for use in the widening range of D.C.L. process stream infra-red liquid and gas analysers, especially for wave-lengths in the 3–15μ region, which is mostly inaccessible to such conventional industrial detectors as the lead-sulphide cell. The detector is linear in response, level insensitive, shockproof, and insensitive to ambient temperature changes, and will enable simple and reliable radiation analysers to be made without moving parts. Although only prototypes have so far been tested, an ultimate sensitivity of the order of 10^{-9} watt is expected.

The principle of the detector is shown in Fig. 1.1. It comprises a small thermocouple loop with a blackened gold-leaf collector disk on each junction, and connected to a multi-turn silver coil. This is sensitively suspended in a permanent magnetic field and provided with a feedback loop and a mirror, which forms part of a light-beam and photocell detector system. Any difference in the amounts of energy falling on the two collectors causes a current to flow in the thermocouple coil, tending to deflect the element in the magnetic field. This deflexion is detected by the photocell, and an amplifier sends a current, *via* the suspension, through the feedback loop, which maintains the element in balance. The output from the detector thus takes the form of this feedback current, which is linearly proportional to the difference in the energies falling on the two blackened disks.

In designing this detector, use was made of the micro-assembly and electronic techniques evolved during the development of the D.C.L.-Servomex oxygen analyser. The extremely fine metal suspension not only provides the essential current feedback facility, but is extremely stable; and its high tensile strength, combined with the fact that the suspended system weighs only a few milligrams, enables the detector to withstand shocks of several hundred *g*. The suspended system is carefully balanced to ensure minimal level sensitivity, and oscillation is completely damped out by the feedback.

As Fig. 1.2 shows, the thermocouple system, mirror and feedback coil are suspended on a single rectangular frame of fine quartz. The mirror is placed as far as possible from the collector disks and faces backwards, thus minimizing interference from the reference light, by keeping it out of the way behind the detector and as far as possible from the collectors. The suspension is attached to torque-free springs in a cylindrical brass body, with suitable cut-aways, which is sealed in a 1 cm o.d. evacuated quartz tube. The quartz transmits wave-lengths up to 3·5μ, and for longer wave-lengths suitable windows must be cemented in front of the collectors.

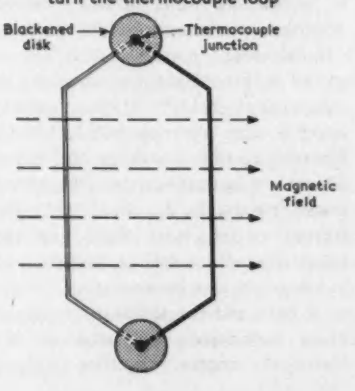


Fig. 1.1 Principle of detector. A difference in the intensity of the radiations falling on the two disks causes unbalanced thermal e.m.f.'s and a consequent circulating current, which reacts with the magnetic field to turn the thermocouple loop

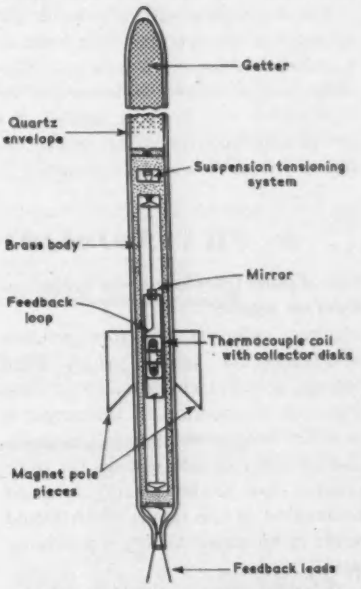


Fig. 1.2 Actual arrangement of null-balance differential radiation detector

For maximum sensitivity and speed of response, the collectors must be allowed to lose as little heat as possible through contact with conductors: for this reason, the thermocouple wires are reduced in thickness

* British patent No. 740374.

to 0·0006in at the junctions, and the quartz envelope is evacuated to a pressure of about 10^{-4} mm of mercury. The evacuation alone increases the sensitivity by 20 to 30 times. The detector is remarkably free of zero drift: general background radiation falling on both disks affects them equally, with no consequent deflexion, and the near-isolation in space of the thermocouple system renders the effect of ambient temperature changes negligible.

The application of the detector in plant stream analysers is readily apparent. Using a suitable optical system, radiation of a selected wavelength from a single source is split and passed through a reference and a sample cell, and the two beams are then focused on respective collector disks. Any difference in energy absorption between the sample and reference appears as a signal from the detector, which is fed into a suitably calibrated indicator or a controller.

The high sensitivity obtainable by suspending the thermocouple loop of a radiation detector directly in a magnetic field was first demonstrated by d'Arsonval and Boys in 1886–7, but the present detector is the first of industrial value to use the principle.

. . . to TRANSMISSION

Use of pulse transformer for radiation-detector signals

Nuclear radiation detectors produce small-amplitude pulses, which often require to be transmitted over long distances. Conventionally the output is amplified before being fed to a counter. The amplifier in such systems has to be situated close to the detector, to avoid attenuation of the input, which would result in an unsatisfactory signal/noise ratio.

The main objection to this arrangement is that the amplifier, being a unit which may require servicing, is necessarily in an inaccessible position in many applications. Plessey Nucleonics have introduced a system whereby the amplifier may be removed to the receiving end of the transmission line, its place being taken by a pulse-transformer located near the detector. The pulse transformer, which is impedance-matched to the transmission line, is a device which is unlikely to require servicing, or to be affected by radiation. In most applications a second pulse transformer is included on the system at the receiving end, on the input side of the amplifier.

. . . to SPEED

Variable-speed a.c. motor

Many systems have been devised for controlling the speed of a.c. motors, but few of these have produced results comparable to those of a shunt-wound d.c. motor — i.e. steplessly variable speed over a wide range. The demand for such a characteristic has usually been met by a Ward Leonard set, in which d.c. produced by an a.c.-energized motor-generator is used to drive a conventional shunt-wound d.c. motor. This method is well-established and gives good results, but is complex and relatively expensive.

A new solution to the problem is provided by a motor designed by T. Mensforth, which is to be manufactured by Mawdsley's Ltd. It is essentially a shunt-wound a.c. commutator motor, in which special measures have been taken to overcome difficulties normally experienced in machines of this type.

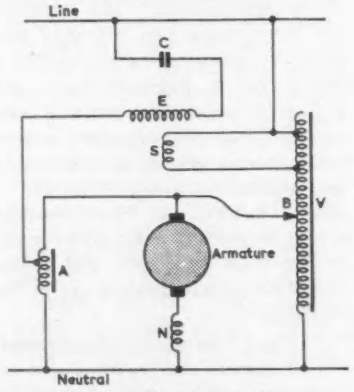


Fig. 3.1 Schematic circuit of variable-speed motor

In all a.c. commutator motors, troubles are caused by the so-called 'transformer' e.m.f.'s which are induced in the armature windings by the alternating field. These spurious e.m.f.'s are short-circuited by the brushes, causing sparking and losses. There are certain established techniques for reducing the effects of 'transformer' e.m.f.'s: these include shunt interpole windings, and current-limiting resistors between the commutator bars and the armature windings. These techniques are used on the Mensforth motor, together with a further compensating technique which ensures that the main excitation is correct in magnitude and phase for all speeds and loads. 'Neutralizing' windings are also incorporated. In conventional motors, these windings neutralize armature reaction and thus reduce the impedance of the armature circuit. In the Mensforth motor, the augmented central ampere-turns of the neutralizing windings also provide the conventional series-interpole effect.

The function of the shunt interpole windings is to induce e.m.f.'s in the armature windings to oppose the 'transformer' e.m.f.'s. This can readily be done on series-wound machines, where no problem of phase difference between field and armature current exists, as the same current flows through both. In shunt machines, however, it is difficult to maintain the correct phase relationship between field and armature currents, particularly if the speed is varied.

The principle of the motor is shown in Fig. 3.1. It will be noted that it is similar to a shunt-wound d.c. motor in that speed regulation is obtained by varying the voltage across the armature. In this case, the position of the slider *B* on the variable transformer provides the adjustment. The main field winding *E* is 'tuned' with the capacitor *C*, so that the voltage across *E* is large compared with the voltage applied across *E* and *C*. The novelty in the design lies in the use of the auto-transformer *A*. If this were not present, and the field winding *E* were connected directly to the neutral, it would be possible to arrange the shunt interpole windings (represented by *S*) to cancel effectively the 'transformer' e.m.f.'s at a particular speed. Since, however, the e.m.f.'s produced by the field due to *S* are proportional to speed, whereas the 'transformer' e.m.f.'s are virtually independent of speed, the 'tuning' would not be correct at other speeds. The auto-transformer *A* provides the necessary compensation. At high speed, the shunt interpoles are fully effective, and the 'transformer' currents are cancelled out so that they do not influence the main field flux. As the speed is reduced by moving the slider *B* towards the neutral, the compensation provided by *S* becomes inadequate, because of the speed effect described above. Interference then takes place between the flux due to the 'transformer' currents and the main

flux, reducing the effectiveness of the field. However, the connexions to the auto-transformer are such that the movement of *B* increases the voltage applied to *E*. These two effects are

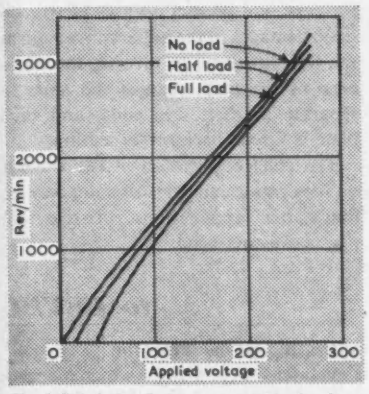


Fig. 3.2 Relation between speed and voltage applied across the armature circuit

approximately linear, and can be made to cancel out.

Thus the field is virtually constant irrespective of the position of *B*, and the machine is analogous to a variable-speed shunt-wound d.c. motor. The relation of speed to the applied voltage (between *B* and neutral) is shown in Fig. 3.2. These curves relate to an initial production 4-pole motor. It is claimed that the machine can operate at constant torque at any speed from 0–3000 rev/min in either direction. Regenerative braking is inherent and requires no additional control equipment.

. . . to FLOW

New mass flowmeters

Instruments for measuring mass flow may be divided into two general classes: (1) those which use the momentum of the fluid to produce a signal or signals from which the mass flow may be computed, and, (2) those in which the reading of a volume flowmeter is corrected as a result of a determination of density by a separate measuring device.

Two new instruments, one in each of the above classes, have recently become available on the European market. Both are 'turbine' types, but they show radically different approaches to the problem. In class (1), the Potter mass flowmeter, which has been available in America for some months, is now to be manufactured in this country by de Havilland. The measuring element of this meter is probably the neatest so far, though the associated electronic equipment is somewhat complex. On the other hand the new Faure Herman mass flowmeter, which falls into class (2), involves a good deal of electro-mechanical complication in the measuring element, but has simpler output equipment.

The rotor arrangement of the Potter mass flowmeter is shown in Fig. 4.1. The two rows of turbine blades, *B* and *C*, rotate about the same axis, and are capable of limited rotation relative to each other. This relative rotation is controlled by a spring (not shown in the diagram) between the two hubs. The two sets of blades tend to rotate in the same sense, but the blade angles of *B* and *C* are different, so that if they were completely free they would rotate at different speeds. At a given flow, the complete rotor assembly rotates at a speed intermediate between the 'natural' speeds of the two sets of blades. This speed is nevertheless strictly proportional to the volume flow, as in a conventional volumetric meter. Because of the difference in blade angle, there will be a relative angular displacement between *B* and *C*, and this will be proportional to the momentum of the fluid. The mass flow is proportional to the time, *t*, taken for this angular displacement to pass a reference point. This may be shown briefly as follows: the time interval, $t, = \theta/\omega$ where θ is the angular displacement referred to, and ω is the angular velocity of the rotor assembly; but θ is proportional to the fluid momentum, i.e. to ρV^2, where ρ is the fluid density and V its velocity; as ω is proportional to V, $t \propto \rho V^2/V$, i.e. $t \propto \rho V$, i.e. t is proportional to the mass flow.

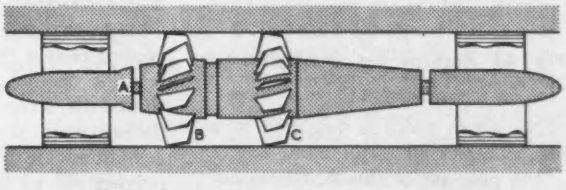


Fig. 4.1 Dual rotor arrangement of Potter mass flowmeter. The relative displacement between the rotors, which have different blade angles, is proportional to the density of the fluid

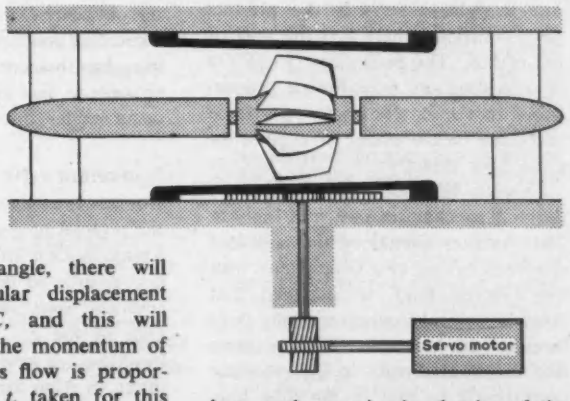


Fig. 4.2 Taper sleeve arrangement of Faure-Herman meter. The sleeve is positioned by the servo-motor, which also drives a potentiometer (not shown) giving a feedback signal representing sleeve position

Each set of blades carries a piece of magnetic material which generates pulses in appropriately placed pick-up coils outside the flow tube. Existing time-interval measuring equipments may be used to measure the time between corresponding pulses from *B* and *C*. The general principle of these equipments is to use the pulses to 'gate' a high-frequency oscillator, the *B* pulse 'opening' the gate and the *C* pulse 'closing' it. A pulse counter can then be used to obtain a digital reading of the time interval.

It will be apparent that, merely by counting the revolutions of the rotor, the volume flow can also be obtained if required, and consequently the fluid density. This instrument is suitable for both gases and liquids, and it retains the principle, used in its volumetric predecessor, for automatically relieving the thrust on the downstream bearing.*

The Faure-Hermann mass flowmeter, shown in Fig. 4.2, is a development of previous meters, in which manual adjustment could be made for known changes in the density of the fluid. A system similar to that used on the manually adjusted meters is now connected by an electric servo-system to a density-sensitive device, so that the adjustment is made automatically.

Referring to Fig. 4.2, it will be seen that the measuring element has a single rotor, and is similar to a conventional volumetric instrument,

* See *Control*, June 1960, p. 123

except that there is a tapered sleeve between the main flow pipe and the rotor. This sleeve is capable of longitudinal movement relative to the rotor, so that the area of the orifice in which the rotor operates may be varied. This adjustment is made to suit the fluid density, so that mass flow is obtained directly from the speed

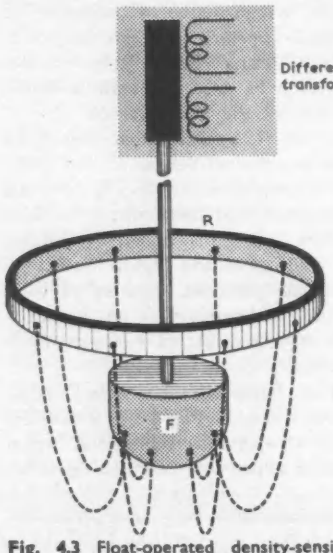


Fig. 4.3 Float-operated density-sensitive device to work with the measuring element of Fig. 4.2

of the rotor, which is measured by a magnetic pick-off in the usual way.

The principle in this case is to adjust the sleeve so that the product ρa is constant, where a is the area of the orifice. The mass flow is ρaV, so if ρa is constant, mass flow is proportional to V. As ω is also proportional to V, the measurement of ω gives the mass flow directly.

Density variations are detected by the float mechanism shown in Fig. 4.3. The float is contained in a sealed chamber having two connexions with the metered fluid, so designed that there is a slow circulation of the fluid through the chamber. This ensures that the fluid density in the chamber corresponds to that in the flow line. The float is completely submerged in the fluid. Being slightly lighter than the volume of fluid it displaces, the float is held in equilibrium by the downward force exerted on it owing to the weight of the pendant chains which join it to the ring R. It will be seen that this force increases as the float rises. There will thus be a range of equilibrium positions for the float, corresponding to different liquid densities.

The position of the float is detected by a differential transformer, the core being connected to the float. A voltage derived from the differential transformer is compared with the voltage across a feedback potentiometer driven from the servo-motor (Fig. 4.2). Any difference between the two voltages is amplified and used to drive the servo-motor in the appropriate direction to restore balance, thus adjusting the position of the tapered sleeve by means of a rack-and-pinion gear, and resetting the feedback potentiometer.

In order to make the system suitable for use in moving vehicles, measures have to be taken to prevent inaccuracies caused by uncontrolled movements of the float. These may be caused by acceleration or by changes in attitude of the vehicle. The density correction equipment will continue to work at moderate accelerations and changes in attitude, but when the limit of satisfactory operation is reached, this part of the system is made inoperative. This is done by the ring R, which is suspended in the chamber in such a way that attitude changes, or accelerations exceeding certain limits, cause it to contact the chamber walls. This action shorts the error signal, so that the sleeve remains stationary until normal conditions are re-established. It is pointed out by the makers that such discontinuities in the action of the correcting mechanism are unlikely to introduce inaccuracies, as appreciable changes in fuel density do not usually occur under disturbed conditions.

Non-return valve for air flow

Conventional valves designed to prevent the reversal of gas flow usually employ a plate which is lifted by the gas pressure, and returns to its seat when the flow reverses. Such valves involve disturbance of the gas flow and consequent head-loss. A new type of valve introduced by Alan Muntz and Co. has been designed to give minimum disturbance of the flow, and is claimed to give quicker operation.

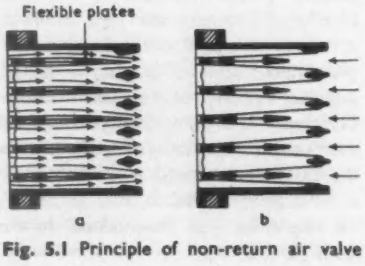


Fig. 5.1 Principle of non-return air valve

The principle of operation is shown in Fig. 5.1. In the open position, the thin flexible plates are held against the formers, and present a series of streamlined passages to the air flow. As soon as the flow attempts to reverse, the resilience of the plates causes the pairs to separate at their free ends, and each plate is forced back on its seating.

The chief application of the valve is on the output line from air compressors, but other applications in chemical plants are envisaged.

. . . to LEVEL

Vibrating-probe detector

Level-detecting devices which depend on interference with physical movement by the substance being detected are finding increasing popularity in some industries. A recent design introduced by Firth Cleveland uses a vibrating probe as a detector; this

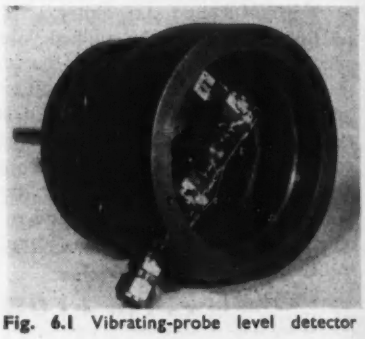


Fig. 6.1 Vibrating-probe level detector

probe vibrates freely when in air, the vibrations being stopped by contact with the material being detected, whether liquid or granular solid.

The probe assembly consists of a metal rod that is supported by a thin diaphragm at its mid point. The diaphragm forms an integral part of the rod, and also provides a seal between the tank or hopper to which the device is fitted and the vibrating mechanism. Vibrations at the natural frequency of the rod are induced by a magnet and coil assembly. When vibration of the rod is inhibited by contact with the material being detected, oscillation of the driving circuit ceases, and a relay is operated to produce the required warning or control action. The detector is claimed to be suitable for most materials, except those which are highly glutinous.

DATA SHEET 23

Practical methods of tuning process control loops

by **M. A. BEECHEY** B.Sc.(Eng.), A.M.I.Mech.E.
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This data sheet presents a practical approach to the problem of establishing optimum controller settings, based upon the frequency response and step function methods of control loop analysis.

To obtain optimum response in a control loop, a knowledge of the frequency response of both controller and process is ideally required, so that the former can be accurately matched to the latter. In practice the effort required to obtain the process frequency response may not be justified, nor may it be permissible to disturb the process for a sufficient time in the manner required.

Two methods are given here for tuning controllers in process control loops. These will be referred to as the 'frequency response' and 'step function' methods respectively. The use of one or both of these methods will normally give results which are sufficiently near the theoretical optimum for practical purposes, without requiring undue time and effort.

FREQUENCY RESPONSE METHOD

The first method described is based upon the frequency response approach. It involves causing the controller and process to operate as a closed loop under conditions of continuous oscillation, and, by successive approximation, determining suitable controller settings from the results obtained.

In establishing the continuous oscillation in the control loop, the amplitude of the oscillations should bear some relation to the normal closed-loop operation that is likely to occur. On the one hand, the amplitude should be large enough for reliable observations to be made. On the other hand it should not greatly exceed the amplitude of deviations likely to occur in practice. If the amplitude employed is too large, the results obtained will be unrepresentative by virtue of any non-linearities inherent in either the process or the control equipment.

Since this method involves obtaining controller settings under operating conditions, it is assumed that the work will be done under normal plant load conditions. However, as in many instances the lag characteristics of a plant change radically with change of load, it may be advisable to repeat the method at the other load values, and produce a compromise in settings. A procedure for doing this is suggested in the final section of this data sheet.

Certain general assumptions have to be made in order to determine how the various control actions are to be adjusted in relation to the performance obtained under continuous oscillation of the control loop.

Proportional action

The criterion of control quality used in this method is that of deviation reduction factor. This is defined briefly as the ratio between the maximum values of the deviations of the controlled condition resulting from a step disturbance (a) when there is no corrective action applied and (b) when the controller is in operation. This implies, of course, that the process possesses inherent regulation.

For a given disturbance, the deviation reduction factor is directly related to the proportional control factor employed. This in turn depends upon the value of the proportional band setting of the controller. The aim in achieving optimum settings can therefore be expressed as that of obtaining the smallest proportional band setting consistent with stability. Since the method involves obtaining settings under conditions of continuous oscillation, a factor has to be applied in order to obtain a damped response. The actual degree of damping desired will depend upon particular process conditions, but in general an acceptable degree of damping will probably be obtained if the proportional band value obtained under conditions of continuous oscillation is doubled. Changes in inherent operating frequency of the control loop between continuous and damped oscillations are ignored as far as their effect on controller settings is concerned.

Integral action

In order to achieve the lowest possible proportional band setting as mentioned above, it is desirable to use the smallest amount of integral action.

The phase lag in the controller resulting from the integral action will then be kept as small as possible. However, the principal function of integral action is to deal with disturbances which necessitate a new mean value of the controller signal, in order to hold the controlled condition at the desired value. The time required for the controlled condition to settle at the desired value following such a disturbance depends partly on the amount of integral action employed. The integral action cannot therefore be reduced indefinitely. In practice it has been found that a satisfactory compromise is normally obtained if the effective integral action time employed is equal to the period of oscillation of the control loop.

Derivative action

The amount of derivative action employed depends in the first instance upon whether the controller mechanism generates it in a 'pure' form.

Deviations from pure derivative action occur owing to the following conditions:

(a) Effect of finite gain in detecting mechanism (e.g. the flapper and nozzle of a pneumatic controller).

(b) Presence of gain limiting devices such as 'derivative stabilizers'.

(c) Interaction with integral action, when the latter is employed in controller circuit not producing pure three-term action.

Since condition (a) only seriously effects the response of the controller at very low proportional band values, this will be ignored.

Consider, firstly, controller circuits not affected by (b) and (c); the gain and phase advance in the output of the controller will increase with increase in derivative action, until the theoretical limits of infinity and 90° respectively are reached, for a controller with proportional plus derivative action. Since, however, the optimum controller response is obtained when the maximum proportional control factor (i.e. minimum proportional band) is employed, a limiting value of derivative action exists which depends upon the lag characteristics of the process.

This limit is reached when any further increase of derivative action will increase the overall controller gain to a greater extent than the attenuation in the process is increased. Beyond this limit the proportional control factor would have to be reduced to retain stability, although the phase advance and operating frequency would be increased. This is undesirable, since the criterion of control quality has been defined as being associated with the proportional control factor, and not solely with the operating frequency.

A process having a characteristic producing only a small rate of increase in attenuation with increase in phase angle does not, therefore, allow much derivative action to be effectively employed. Such a lag characteristic is typical of processes having considerable distance velocity lag, or transfer lag resulting from multiple transfer stages.

The method of establishing the optimum derivative action is, therefore, to increase it until conditions of continuous oscillation are obtained with the minimum proportional band setting.

The effect of 'derivative stabilizers' will now be considered. A derivative stabilizer forms a partial bypass of the derivative resistance in the controller circuit. Its effect depends on the ratio of the change in signal from the detecting mechanism of the controller and the resultant change in proportional signal.

The equation of such a controller for proportional and derivative action is:

$$P + \frac{r}{n}\frac{dP}{dt} = -K\left(r\frac{d\theta}{dt} + \theta\right)$$

where P = output signal
θ = deviation of controlled condition from desired value
r = time constant of derivative action
n = ratio defined above
K = proportional sensitivity $= \dfrac{100}{\text{proportional band}}$

With such a controller action a maximum angle of phase advance is obtained when $r = T\sqrt{n}/2\pi$, where T is operating period. (The angle of phase advance is then $\tan^{-1}(n-1)/2\sqrt{n}$. If the value of n is small (say less than 4) then this limited angle of phase advance may be less than the value which could be obtained with pure derivative action, when matching the controller to the particular process. The procedure of tuning the controller would, however, be the same, namely to increase the derivative action until the minimum proportional band were made possible.

For controllers having pure three-term action, the procedure for establishing the optimum derivative action is similar to that for those with proportional and pure derivative action, except for the additional requirement of equating the integral action time to the prevailing operating period.

With three-term controllers possessing interaction characteristics, however, the requirement for equating the effective integral action to the period produces a limit to the angle of phase advance possible in the controller output. This limit is obtained with a certain value of derivative action.

The degree of interaction in such a controller depends upon its design, but the controller output equation can be expressed generally as follows:

$$P = -I_1K\left(\frac{r}{I_2}\frac{d\theta}{dt} + \theta + \frac{1}{I_2 s}\int\theta\,dt\right)$$

I_1 = interaction factor affecting overall controller gain
I_2 = interaction factor affecting integral and derivative action
r = time constant of derivative action
s = time constant of integral action
P = output signal
θ = deviation from desired value
K = proportional sensitivity $= \dfrac{100}{\text{proportional band}}$

The effective proportional, integral and derivative actions (i.e. those equivalent to the values which would be obtained if the controller were pure term) are as follows:

Effective integral action, $S = I_2 s$
Effective derivative action, $R = r/I_2$
Effective proportional action $= I_1K$

If the effective integral action S is to be equated to the prevailing operating period, the maximum phase advance in the controller output will be obtained if a certain value of r/s is maintained. This ratio depends upon controller design, and is normally specified by the manufacturers.

In certain cases, the optimum ratio of r/s cannot, however, be employed owing to its effect on the value of the interaction factor I_1, which affects the proportional sensitivity.

In a 'parallel connected' controller (i.e. one in which the resistance-capacity units forming the integral and derivative sections of the controller feedback circuit are fed in parallel from the controller relay), the optimum phase advance would in theory be obtained when r and s were equal. This, however, would produce a value of I_1 equal to infinity, all negative feedback effect being annulled. In such instances, therefore, a value for r/s is specified (e.g. 1/3) which produces the maximum phase advance consistent with a reasonably low value of I_1.

When tuning an interacting three-term controller to a process, it is advisable to start by assuming that the maximum phase advance obtained from above considerations can be accepted by the plant lag characteristics, in order that the first approximation of equating the effective integral action to the operating period can be conveniently handled. If, however, it is then suspected that the lag characteristics are such that less phase advance will permit a smaller proportional band to be used a smaller value of r/s can be tried. In such circumstances, it may be found in practice that the amount of derivative action may be thus so limited as to be hardly worth employing at all. The simplification of the controller circuit resulting from its removal may then well be justified.

SUMMARY OF PROCEDURE FOR FREQUENCY RESPONSE METHOD

The following steps form a condensed procedure based upon the foregoing considerations:

1. Proportional action

a Adjust proportional band to obtain continuous oscillation
b At least double proportional band to obtain stable response

2. Proportional plus integral action

a Temporarily dispense with integral action*
b Adjust proportional band to obtain continuous oscillation
c Set integral action time equal to period of oscillation†
d At least double proportional band to obtain stable response

3. Proportional plus derivative action

a Temporarily dispense with derivative action (Normally this can be done by setting the adjustment as near as possible to zero)
b Adjust proportional band to obtain continuous oscillation
c Set derivative action time initially to, say, 1/20 of period of oscillation. (This is an arbitrary figure, which should be sufficient to show the effect of introducing derivative action, but which will normally be less than the final optimum setting. If the arbitrary value is much above the optimum, the proportional band will have to be increased to re-establish continuous oscillation; the derivative action will then have to be reduced.)
d Readjust proportional band to obtain continuous oscillation.
e Provided that this adjustment is a reduction in proportional band, increase derivative action (to say 1/10 of new period of oscillation).
f Readjust proportional band as above
g Repeat procedure until minimum proportional band is obtained for continuous oscillation.
h Finally, at least double proportional band to obtain stable response.

4. Proportional plus integral plus derivative action (pure term controller

a Temporarily dispense with integral action*
b Temporarily dispense with derivative action
c Adjust proportional band to obtain continuous oscillation
d Set integral action time equal to period of oscillation
e Set derivative action time initially to, say, 1/20 of period of oscillation
f Readjust proportional band to obtain continuous oscillation (provided reduction in value is possible)
g Reset integral action to period of new oscillation
h Increase derivative action to, say, 1/10 of period of new oscillation
i Readjust proportional band as above
j Repeat procedure with increase of derivative action until minimum proportional band is obtained. The integral action should also be reset if period of oscillation alters appreciably
k Finally, at least double proportional band to obtain stable response

5. Proportional plus integral plus derivative action (interacting controller)

a Temporarily dispense with integral action*
b Temporarily dispense with derivative action
c Adjust proportional band to obtain continuous oscillation
d Set integral action time so that effective integral action (taking into consideration the interaction factor) equals the period of oscillation
e Set derivative action time so that prescribed ratio between derivative and integral action times (r/s ratio) is obtained
f Readjust proportional band to obtain continuous oscillation
g Readjust integral action time so that effective integral action equals period of new oscillation
h Readjust derivative action time to maintain r/s ratio
i Readjust proportional band to obtain continuous oscillation
j At least double proportional band to obtain stable response

Note

If derivative action appears excessive (see earlier comments on interacting three-term controllers) decrease derivative action and readjust proportional band. If a decrease in proportional band is found possible, continue decreasing derivative action until minimum proportional band is obtained.

* The method of dispensing with integral action depends upon the design of the controller. In most pneumatic controllers this can be done by sealing a signal of suitable value for the prevailing load in the integral chamber behind a closed integral valve.
† Since under these conditions the phase lag in the controller output introduced by integral action is only about 9°, it is unlikely that the operating period will be changed sufficiently to merit a second approximation involving the resetting of the integral action.

STEP FUNCTION METHOD

This method of tuning a controller to a process is based on work carried out by Ziegler and Nichols (*1*), and involves applying a step in the signal to the process regulator whilst the controller is out of commission. This step is applied at the controller output, and will therefore include any lag in the transmission of this signal to the regulator, and in the response of the regulator itself. The result of this step is then measured in terms of the controlled condition at the controller input, and will thus include all measurement lag.

The size of signal step chosen should be sufficient to result in a response which can be easily analysed, but not so large as to introduce the effects of any non-linearities in the part of the control loop involved. The mean level of the step should be approximately that at which the control loop will be ultimately operating and the process load should be of a similar value. If non-linearities are unavoidable in spite of the above precautions, it may be necessary to carry out two steps, one in each direction and work on mean results.

Fig. 1 shows a graphical representation of the general form of response obtained from a step function applied as above. The response to the step applied (ΔP, expressed as a percentage of range of control signal), has two principal characteristics denoted by L and R.

R is defined as the slope of the tangent to the response curve at the point of maximum rate of change, i.e. the point of inflexion. Its units are percentage of full-scale range of measuring instruments per minute.

L is defined as the intercept on the time axis between the point at which the step is applied and the point at which the above tangent cuts the time axis drawn through the initial value of the controlled condition. Its units are minutes.

Process controllability is dependent upon the combined effect of these two factors. This is demonstrated graphically by the value of the intercept C on the vertical axis. The larger this intercept, the smaller will be the controller gain permitted by stability requirements.

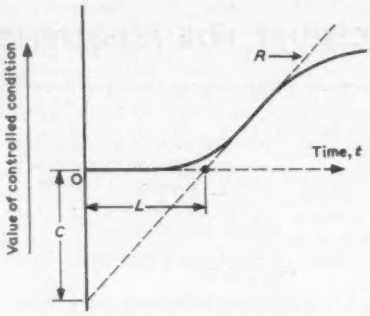

Fig. 1 Typical step response

The formulae given by Ziegler and Nichols for controller settings with various actions are as follows. These are for a damped response with subsidence ratio of about 4 to 1.

Proportional control.
Proportional band = 100 $RL/\Delta P$ %

Proportional plus integral control.
Proportional band = 110 $RL/\Delta P$ %
Integral action time = 3·3 L min

Proportional plus integral plus derivative control
Proportional band = 83 $RL/\Delta P$ %
Integral action time = 2 L min
Derivative action time = 0·5 L min

Note
The integral and derivative settings for three-term control are related to a particular type of controller as far as interaction factor is concerned. Since Ziegler and Nichols also stated a general relationship for the plant operating period for continuous oscillation of $T = 4L$, these action times are related to this period as follows:

Integral action time s = 0·5 T
Derivative action time r = 0·125 T
(Hence r/s ratio = $\frac{1}{4}$)

APPLICATION OF THE TWO METHODS

1. The relative applicational merits of the frequency response and step function methods of establishing controller settings depend a lot on particular process conditions. Both methods involve a certain degree of plant disturbance, and one type of disturbance may be more tolerable than the other. The frequency response method involves the greater effort, but it has the advantage of being more exact. It takes into consideration the precise controller characteristics, and the ultimate setings obtained are conclusively those which produce a satisfactory response that has been obtained with the whole system operating as a closed loop. The extent of the safety factor employed on the proportional band to ensure stability is also known. The step function method on the other hand can be very useful in providing initial settings before the controller is brought into action and can, therefore, also be used in conjunction with the frequency response method as an initial measure.. It would, however, be an impracticable method to use on control loops in which the reaction rate is too fast for readings to be conveniently taken. At the other extreme, the values of R and L cannot accurately be assessed when the reaction rate is very slow. The presence of noise in the measurement of the controlled condition also produces difficulties in this respect, whereas with the frequency response method it is usually possible to determine the fundamental frequency of the control loop under such conditions.

2. Any method of establishing controller settings is affected by the problem of change in plant characteristics with change in load. These conditions may require completely different combinations of settings of all three actions. As far as overall controller gain is concerned, this can be dealt with to a certain extent by a suitably characterized regulator. The requirement for different integral and derivative actions, however, can only be dealt with in the conventional single-loop controller by effecting some form of compromise. For instance, the derivative action can be set to suit the shortest oscillating period and the integral action the longest period. This means using a much smaller ratio between the two actions, and thus reducing the controller phase advance. It ensures, however, that the controller gain cannot be increased beyond its stability limit as the result of a change in inherent control loop frequency.

3. The controller settings established by the methods described above take in account only the stability requirements of the process loop determined by the procedures laid down. Other factors will then have to be considered when such settings are applied, in case they should have any overriding limitation upon them.

For instance derivative action may have to be reduced if considerable noise is present in the measurement of the controlled condition, in order to avoid excessive regulator action, which would inject undesirable disturbance into the process.

A further example of the need to modify such controller settings occurs in processes involving several individual control loops, where regulation in one loop can inject disturbance into another loop. In such instances the adjustment of controller settings often has to be an overall compromise. Controller sensitivity in one loop has to be reduced, and control quality thus sacrificed, in order to reduce disturbance and hence increase control quality in the other loop. The worst problem of this kind occurs when such individual control loops interact with one another owing to mutual disturbance effects, coupled with similar inherent control loop frequencies. In such cases the controller sensitivities have to be reduced considerably below those values determined by stability requirements based on consideration of individual loops by themselves, otherwise the whole system acting together will be unstable.

Since it is possible to alter the inherent frequency of the control loop by changing the controller action, it might be possible to separate the two frequencies of interacting control loops by a sufficient amount to avert such interaction. This, however, depends very much on the particular process characteristics since, to avoid the possibility of interaction, their operating frequencies would have to be altered to give at least a 3:1 ratio between their respective values.

Reference

1. Ziegler, J. G. and Nichols, N. B.: 'Optimum Settings for Automatic Controllers', *Trans. A.S.M.E.*, 1942, *64* (Nov.), p. 759

CONTROL 21 SURVEY

Foreign-language periodicals

for the control and instrument engineer

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TITLE	PUBLISHER	LANGUAGES	FREQUENCY AND ANNUAL SUBSCRIPTION*	FIELD	NATURE OF CONTENTS	READERS SERVED
Automatizace (Automation)	Edited by Ministry of General Engineering, sponsored by Czechoslovak Scientific-technical Society for Spreading Political and Scientific Knowledge, issued by Publishers of Technical Literature, Krakovska Ul.8, Prague 1, Czechoslovakia	Czech; English, Russian, German and French contents-lists and summaries	Monthly £3 10 0	Automatic control	Theory and design, equipment, news, practice	Research workers, design and development engineers
Jemná Mechanika a Optika (Precision Mechanics and Optics)	Published for the Ministry of General Engineering by the State Publisher of Technical Literature, Narodni Podnik, Spalena Ul.51, Prague 2-Nove Mesto, Czechoslovakia	Czech; English, Russian and German contents-list and summaries	Monthly £2 13 7	Optics and measuring instruments	Research reports, survey articles, equipment, theory and design	Research workers, design and development engineers
Automatisme (Automation)	Dunod, 92 rue Bonaparte, Paris 6e, France	French	Monthly £3 11 0	Control, data transmission and handling	Research reports, theory and design, practice, equipment, news	Research workers, design and development engineers, plant and application engineers
Automation (Automation)	Les Nouvelles du Monde, 6 rue de Liège, Paris 9e, France	French	Monthly £2 2 0	Industrial automation	Practice, equipment, news	Plant and application engineers, technical management
Mesures et Contrôle Industriel (Measurements and Industrial Control)	Committee for Technical Publications, 79 Avenue des Champs Elysées, Paris 8e, France	French; English and German contents-lists*	Monthly £4 0 0	Industrial instrumentation and control	Survey articles, theory and design, practice, equipment, news	Research workers, design and development engineers
Archiv für Technisches Messen und Industrielle Messtechnik (Archive for Technical Measurement and Industrial Measurement Technology)	R. Oldenbourg K.G., Rosenheimer Strasse 145, Munich 8, Germany	German	Monthly £4 4 0	Scientific and technical measuring instruments and methods	Survey articles, equipment, news	Research workers, design and development engineers
Automatik (Automation)	R. v. Decker's Verlag, Heimhuder Strasse 53, Hamburg 13, Germany	German; English and French contents-lists and summaries	Monthly £3 6 0	Industrial instruments and control	Survey articles, practice, news	Plant and application engineers, technical management
Automatisierung (Automation)	Karl M. Hageneier Verlag, Bergstrasse 146, Heidelberg, Germany	German; English and French contents-lists and summaries	Monthly £3 6 0	Industrial automation	Survey articles, practice, equipment, news	Plant and application engineers, technical management
Feingeräte Technik (Precision Instrument Technology)	Chamber of Technology, Professional Group for Machine Construction. Verlag Technik, Oranienburger Strasse 13/14, Berlin C.2, Germany	German; English, French and Russian contents-list	Monthly £3 6 0	Precision instruments	Survey articles, design, practice, news	Research workers, design and development engineers, technical management
Feinwerktechnik (Precision Mechanism Technology)	Society of German Engineers—Professional Group for Precision Mechanisms, Klopstockstrasse 35, Berlin-Zehlendorf, Germany	German	Monthly £4 6 0	Precision instruments	Survey articles, theory and design, practice, new, equipment	Research workers, design and development engineers
Regelungstechnik (Control Technology)	Published for the Society of German Engineers, the Society of German Electrotechnologists, the Committee for Control Technology of the German Standards Committee, and the Standards Committee for Measurement and Control of the Chemical Industry, by R. Oldenbourg K.G., Rosenheimerstrasse 145, Munich 8, Germany	German; English contents-list	Monthly £4 4 0	Control engineering	Survey articles, theory and design, equipment, news, literature survey	Research workers, design and development engineers, plant and application engineers
Regelungstechnische Praxis (Control Practice) Supplement to *Regelungstechnik*	As above	German	Quarterly 8 0	Practical applications of industrial instrumentation and control	Survey articles, equipment, practice, news	Plant and application engineers, technical management
Technische Informationen Feinmechanik und Optik (Technical Information Precision Mechanics and Optics)	Society for the Advancement of Precision Mechanics and Optics, Habsburgerring 2–12, Cologne, Germany	German	Monthly £5 10 0	Scientific and industrial measuring and control instruments	Equipment surveys	Research workers, design and development engineers, plant and application engineers. Technical management
Zeitschrift für Instrumentenkunde (Periodical for Instrument Science)	Friedr. Vieweg, Burgplatz 1, Brunswick, Germany	German; English, French and Spanish contents-lists and summaries	Monthly £3 14 0	Scientific and technical measurements and measuring instruments	Research reports, survey articles, theory and design, equipment, news	Research workers, design and development engineers
Zeitschrift für Messen, Steuern, Regeln (Periodical for Measurement, Control and Regulation)	Published for Chamber of Technology, Professional Group for Control Technology and Group for Mechanization and Automation, by Verlag Technik, Oranienburgerstrasse 13/14, Berlin C-2, Germany	German; English, Russian and French contents-lists	Monthly £4 8 0	Industrial instrumentation and control	Survey articles, theory and design, practice	Research workers, design and development engineers, plant and application engineers

Continued on page 116

TITLE	PUBLISHED	LANGUAGES	FREQUENCY AND ANNUAL SUBSCRIPTION*	FIELD	NATURE OF CONTENTS	READERS SERVED
Mérés es Automatika (Measurement and Automation)	Scientific Union for Automation and Measurement Technology, Szabadsag Ter. 17, Budapest, Hungary	Hungarian; English, German and Russian contents-lists	Monthly £1 4 0	Scientific and industrial measurements and control	Research reports, survey articles, theory and design, equipment	Research workers, design and development engineers
Automazione e Automatismi (Automation and Automatic Machines)	Institute for Automation, via Fabio Filzi 21, Milan, Italy	Italian; English, French and German contents-lists and summaries	Two-monthly £2 18 0	Industrial automation	Practice, equipment, news	Plant and application engineers. Technical management
Automazione e Strumentazione (Automation and Instrumentation)	Italian National Association for Automation under the patronage of the National Council of Research, via Marcona 15, Milan, Italy	Italian; English, German and French contents-lists and summaries	Monthly £4 12 0	Automation and instrumentation	Research reports, survey papers, practice, equipment, news	Research workers, design and development engineers, plant and application engineers
Keisoku (Journal of the Society of Instrument Technology, Japan)	Society of Instrument Technology, Japan. c/o Department of Applied Physics, Faculty of Engineering, University of Tokyo, 1, Motafujicho Bunkyo-ku, Tokyo, Japan	Japanese; English contents-list and summaries	Monthly £1 8 0	Scientific and industrial measurements and instrumentation	Research reports, theory and design, practice equipment	Research workers, design and development engineers, plant and application engineers
Archiwum Automatyki i Telemechaniki (Archive of Automation and Remote Control)	Published for Polish Academy of Sciences, Institute of Automation by State Scientific Publishing House, Miodowa 10, Warsaw, Poland	Polish; English and Russian contents-lists and summaries	Quarterly £2 4 0	Automatic control	Research reports, theory and design	Research workers, design and development engineers
Pomiary, Automatyka, Kontrola (Measurements, Automation, Control)	Published for Polish Committee for Measurements and Automation and Section for Metrology and Precision Mechanics of the Society of Polish Mechanical Engineers by Chief Technical Organization, Czackiego 3/5, Warsaw, Poland	Polish; English, French, German and Russian contents-lists	Monthly £2 11 0	Measurements, precision mechanics, optics, automatic control	Theory and design, survey articles	Research workers, design and development engineers
Automatica si Electronica (Automation and Electronics)	Scientific Association of Engineers and Technicians of the Rumanian People's Republic, Str. Ion Ghica 3, Bucharest, Rumania	Rumanian; English, French, German and Russian contents-lists and summaries	Two-monthly £2 17 2	Instrumentation, control, industrial electronics	Survey articles, theory and design, practice	Research workers, design and development engineers
Cálculo Automático y Cibernética (Automatic Computation and Cybernetics)	Spanish Cybernetics Society. Conde de Penalver 19, Madrid, Spain	Spanish	Quarterly £1 15 0	Instruments, automatic control, computation	Research reports, survey articles, news, abstracts	Research workers, design and development engineers
Avtomatika (Automation)	Institute of Electrotechnology of the Academy of Sciences of the Ukrainian S.S.R., Vulitsa Chkalova 556, Kiev, U.S.S.R.	Ukrainian; English and Russian contents-lists and summaries	Two-monthly £2 5 0	Automatic control	Research reports, theory and design	Research workers, design and development engineers
Avtomatika i Telemekhanika	Academy of Sciences of the U.S.S.R., Division of Technical Sciences, Institute for Automation and Telemechanics, Kalenchevskaya Ul. 15a, Moscow I-53, U.S.S.R.	Russian; English contents-list and summaries	Monthly £6 6 0	Automatic control	Research reports, theory and design	Research workers, design and development engineers
Automation and Remote Control†	Instrument Society of America, 313 Sixth Avenue, Pittsburgh, Pa, U.S.A.	English	Monthly £13 6 0		Complete English translation of above	
Izmeritel'naya Tekhnika	Committee of Standards, Measures and Measuring Instruments of the Council of Ministers of the U.S.S.R., Shchuseva Ul.4, Moscow K-1, U.S.S.R.	Russian	Monthly £1 14 0	Scientific and technical measuring instruments and methods	Survey articles, news, equipment, research reports, theory and design, practice	Research workers, design and development engineers
Measurement Techniques†	Instrument Society of America, 313 Sixth Avenue, Pittsburgh, Pa, U.S.A.	English	Monthly £9 16 0		Complete English translation of above	
Izvestiya Akademii Nank S.S.R. Otdelenie Tekhnicheskikh Nank, Energetika i Automatika (Bulletin of the Academy of Sciences of the U.S.S.R., Technical Sciences Division, Energetics and Automation)	Academy of Sciences of the U.S.S.R., Griboedova 4, Centr. Ul., Moscow, U.S.S.R.	Russian	Two-monthly £3 10 0	Electrical engineering automatic control	Research reports, theory and design	Research workers
Mekhanizatsiya i Avtomatizatsiya Proizvodstva (Mechanization and Automation of Production)	State Committee of the Council of Ministers of the U.S.S.R. for Automation and Machine Construction, Kiselnyi Per. 5, Moscow, U.S.S.R.	Russian; English and German contents-lists	Monthly £2 16 0	Industrial automation	Survey articles, theory and design news, equipment	Research workers, design and development engineers, plant and application engineers, technical management
Priborostroenie	State Committee of the Council of Ministers of the U.S.S.R. for Automation and Machine Construction, and the Central Directorate of the Scientific-Technical Society of the Instrument Construction Industry, I-yi Basmannyi Per D.3., Moscow B-66, U.S.S.R.	Russian; English and German contents-lists	Monthly £2 2 0	Industrial scientific measuring and control instruments and systems	Survey articles, theory and design, practice, equipment	Research workers, design and development engineers
Instrument Construction† (Translation of above)	Produced for the D.S.I.R. by B.S.I.R.A., Chislehurst, Kent. Published for Taylor Francis Ltd, Red Lion Court, Fleet Street, London E.C.4	English	Monthly £6 0 0		Complete English translation of above	
Pribory i Tekhnika Eksperimenta	Academy of Sciences of the U.S.S.R., Moscow University Physics Faculty, Leninskie Gory, Moscow B-234, U.S.S.R.	Russian	Two-monthly £4 4 0	Scientific measuring instruments and methods of measurement	Survey articles, research reports, theory and design, practice, equipment	Research workers, design and development engineers
Instruments and Experimental Techniques†	Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pa, U.S.A.	English	Two-monthly £9 16 0		Complete English translation of above	

* Approximate annual subscription to general readers.

† Publication date will not coincide with that of original Russian journal.

This month's contribution from our special correspondents in the United States is concerned mainly with the control of the various phases of the flight of a recoverable space vehicle

Look at America

Control of a recoverable space vehicle

Much work has been accomplished and many designs have been proposed for attitude control schemes in ballistic vehicles. Often the schemes are specific to a particular flight regime, such as boost phase or orbit phase. When the design is restricted in this manner, the chances of obtaining a more nearly 'optimum' control system are increased. But one of the most challenging aspects presented by a space mission, particularly one that is manned, is the fact that the different flight regimes encountered require widely different *forms* of control, and that the *purpose* of the control also will change depending on what phase of the flight path the vehicle is in. It is in this light that an excellent review of space-borne attitude control systems is presented by Marx (*1*).

To illustrate the more important considerations, a mission is selected which requires attitude control in several important regimes. Fig. 1 denotes the critical phases (boost, orbit injection, orbit, orbit ejection, re-entry, and landing) in the flight of a manned, recoverable, orbital vehicle. Considering present-day capabilities and the probable payload of a manned vehicle, it seems most likely that a three-stage rocket will be required, the first stage of which is used only during boost. The second and third stages will be required to achieve orbit, and the third stage must be capable of leaving orbit, re-entering, and landing.

Boost phase

In general, the dynamics of the vehicle during boost are inherently unstable (the problem is similar to that of balancing a pencil on one's fingertip and accelerating it upward). A generalized open-loop representation could be

$$\dot{\theta}/\delta = K_\theta(1 + sT_\theta)/(1 - s/T_1)(1 + s/T_2)$$

where θ is the attitude angle away from vertical; δ is the deflexion of the thrust vector; T's are relevant system constants.

In addition, the vehicle elasticity must normally be taken into account, and the time lags associated with the engine 'gimbaling' are also important. One possible control scheme for this phase of flight is shown in Fig. 2. Simple rate feedback with lead-lag compensation is employed, and an integral controller is used to eliminate steady-state errors. As the open-loop gain of this system is increased, the inherent instability is eliminated, but the structural mode is in danger of resonating. It is therefore necessary to make the open-loop gain very high so that the overall transfer function becomes the inverse of the feedback loop, and both structural and inherent stability are eliminated.

THIS MONTH

Space-vehicle control
Computer progress

This system will work satisfactorily if the vehicle characteristics, both structural and aerodynamic, remain constant. This is generally not the case, however, since large amounts of fuel and oxidizer are rapidly consumed and this considerably changes both the mass and stiffness of the vehicle. Also, the increasing speed and decreasing air-density cause significant changes in the aerodynamic forces present. Hence an adaptive controller, as shown in Fig. 3, may be more suitable. It is essentially the same scheme as Fig. 2, except that the system's natural frequency is constantly monitored. Deviations from the desired value are used to adjust the system gain so that the natural frequency remains constant at a predetermined 'best' value. This allows the control to have maximum effectiveness throughout the boost phase.

Orbit phase

Once in orbit, it is most likely that the vehicle will be required to maintain alignment with some vertical relative to the earth. This will require relatively slow, but highly precise rotation of the vehicle about its own axis. Since the orbit is always, to some extent, elliptical, this rate of rotation is not uniform, but rather sinusoidal in nature. Two possibilities present themselves for control in this phase. The first is the use of inertial reaction devices such as flywheels or large gyros. These may be somewhat heavy in terms of hardware weight, but require almost no fuel to power them. For

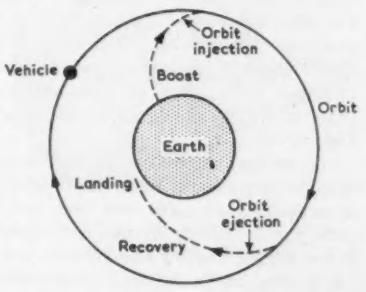


Fig. 1 (above) Important phases in vehicle flight

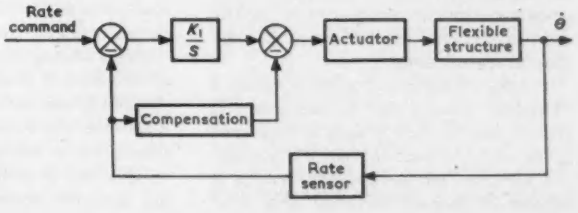
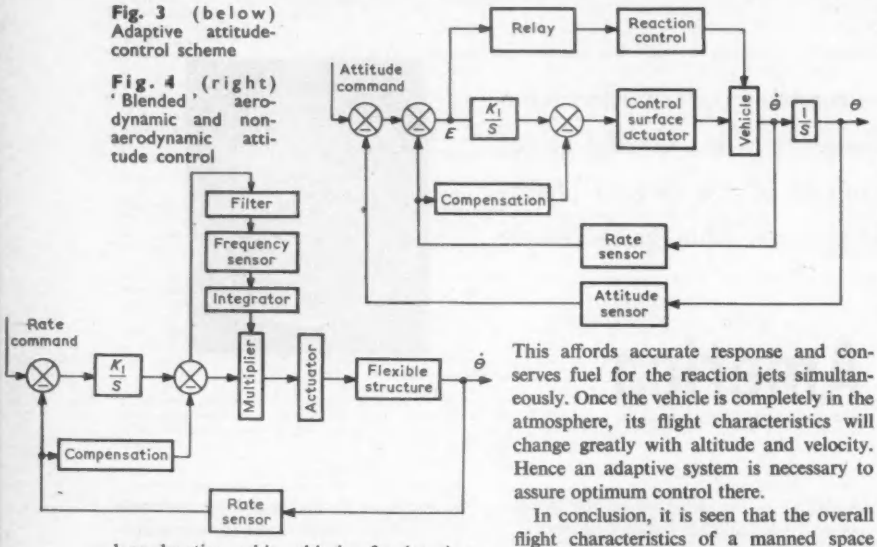


Fig. 2 (right) Proportional control of vehicle attitude rate

Fig. 3 (below) Adaptive attitude-control scheme

Fig. 4 (right) 'Blended' aerodynamic and non-aerodynamic attitude control



long-duration orbits, this is of prime importance.

In a manned flight, however, the duration is shorter, and a mass-expulsion system may be feasible. These are attractive because of their simplicity, reliability, and low initial hardware weight. They are also well suited to on-off or relay control which has certain advantages over continuous control, where the tolerable error is extremely small. In the on-off system, the inherent limit cycle is chosen to lie within the error requirements. The limit cycle may be preferable to the drift and threshold problems which are implicit in a continuous system. Notice that the vehicle dynamics during orbit will be virtually invariant for its duration, hence adaptive control is unnecessary, whereas considerations of weight, reliability, and accuracy are of utmost importance.

Recovery phase

In the recovery phase, the vehicle traverses from a completely non-aerodynamic regime to a completely aerodynamic regime. It leaves orbit by changing its velocity in exactly the proper manner, which may be accomplished by firing retro jets when the satellite is properly aligned. Since the available power for retro jets is limited, and the re-entry trajectory must be precise in order to avoid the adverse effects of excessive heating or falling into the ocean, accurate control of this phase is also required. Here too an on-off scheme seems suitable owing to the difficulty of using proportional valving with the hot gases in the retro jets. During the transition, a critical period exists when aerodynamic control can be used to augment the retro jets but is not yet sufficient to replace them.

To take full advantage of this situation, a 'blending' scheme, like the one shown in Fig. 4, may be used. Owing to dead zone in the relay, the reaction control is inoperative whenever the aerodynamic control is capable of keeping the error near zero. This affords accurate response and conserves fuel for the reaction jets simultaneously. Once the vehicle is completely in the atmosphere, its flight characteristics will change greatly with altitude and velocity. Hence an adaptive system is necessary to assure optimum control there.

In conclusion, it is seen that the overall flight characteristics of a manned space vehicle vary so widely that no one optimization criterion can be applied. Rather, a combination of different schemes must be found that satisfy the overall requirements of accuracy, reliability, weight, safety, and flight duration.

Computer progress

An *ad hoc* group of the A.I.E.E. Computing Devices Committee reported at the recent A.I.E.E. General Meeting that 1960 was the first year in which solid-state computers were installed on a commercial basis in the U.S. (*2*). The change was apparently so sudden that no significant new machine appeared in 1960 that did not use solid-state circuitry.

New large-scale general-purpose solid-state computers include the IBM 7090 with its 2·3μs memory, the Philco 2000, and the CDC-1604. Likewise, new solid-state data processers put into service include the RCA-501, IBM-7070, and the Remington Rand 'Solid State 80'. Remington Rand also put into service its Larc, the first computer with the capability of several IBM 7090s or Philco 2000s. The new small computer systems introduced include the IBM-1401, CDC-160, Monrobot X1, and Packard Bell 250.

The Sylvania Mobidic (Sylvania 9400) and the Remington Rand AN/USQ-20 (Remington Rand 1206) were built especially for a military environment. Like several other special-purpose military computers, these both emphasize the multiple-channel input/output capability required for many military real-time systems.

Rapid advances evident in the application of computers to problems of design, evaluation and simulation have most certainly been due to the improvement in equipment performance as well as the development of more versatile and powerful techniques of applying available equipment. An interesting example of the new applications is the use of computers in the mechanization of the design process.*

The electric utility industry has probably been the most active in introducing on-line control computers. A number of computers has been installed for data collection, process monitoring, calculation of operating guides, economic dispatch of generation and interchange billing, and automatic start-up and shut-down of boiler-turbine-generator units. Most significant was the announcement that the digitial computer at the Sterlington Station of Louisiana Power and Light successfully passed a six-month acceptance test, with better than 99% availability.

In the petro-chemical field, B. F. Goodrich has reported favourably on the computer control of a vinyl chloride plant and an acrylic plastic plant. Likewise, Monsanto has reported favourably on their computer-controlled ammonia plant.

Automation has also made its impact on heavy industry, particularly the steel industry. Jones and Laughlin has a computer-controlled continuous annealing line in operation, and Great Lakes should have an automatic hot-strip mill by the end of the year. Automated blast furnaces and open-hearth furnaces are also in progress.

In the area of computer simulation, striking applications have begun to appear in the medical profession. An interesting example is the Rand Corporation's simulation for the Air Force of the physical chemistry of the human respiratory and circulatory systems. Considered in the dynamic simulation are the partial pressures of the constituents of the inhaled and exhaled air, the mixing in the lungs, the transport in both directions through the membranes of the blood cells, and the chemical composition of the blood cells—in all, some 53 interdependent variables.

Perhaps the most challenging of all the applications has been the development of so-called intelligent machines. We have seen examples of computers which can, to some degree, learn from experience, recognize patterns, organize themselves, adapt their responses to changing conditions, or in some other ways display what can be considered some degree of intelligence. Attempted computer simulations of the human thought process have yielded some important information about how the brain might work, as well as how the computers themselves might be made to work better.

Your American Correspondents

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* See 'Look at America' for April 1961.

Testing gyros at B.A.C.'s Instrument Wing

Closed-loop operation determines error torques

DURING A RECENT VISIT TO THE Instrument Wing of English Electric Aviation's Guided Weapons Division at Stevenage, Hertfordshire, *Control* saw something of the work carried out there in developing, producing and testing gyroscopes. Part of the British Aircraft Corporation, this factory produces gyros for inertial navigation systems, and the high accuracy and reliability required of these components entails their manufacture under conditions of quite fanatical cleanliness in areas isolated from vibration. Some 40% of the Wing's output of gyros is used in the English Electric *Thunderbird* ground-to-air weapon, and in English Electric's *Blue Water*, the ground-to-ground, 70-mile range missile for the Army.

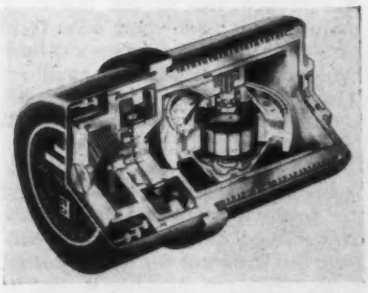
The Mig gyro

When English Electric first started development of *Blue Water*, they took out a licence with Minneapolis-Honeywell Regulator for the manufacture of the latter's miniature integrating gyroscope—the Mig—for use in the weapon's inertial navigation system. The floated rate-integrating gyro is based on the work of Dr C. S. Draper of the Massachusetts Institute of Technology, and its design is such that bearing friction is eliminated to a very large extent. Error torques due either to gimbal unbalance or to restraints from gimbal-position sensors and power supply leads are also very small. The Mig (Fig. 1) is of miniature design—a typical model, the GG49D, measures 1·83in in diameter by 2·796in in length and weighs 0·48 pounds—is robust enough to accept shocks up to 100 *g* and, being hermetically sealed, is relatively insensitive to climatic conditions.

The actual gyroscopic element is a sealed cylindrical gimbal containing the spin motor which is a.c. powered. This gimbal is enclosed in a hermetically sealed outer case incorporating a heater and a temperature-sensing element, and is pivoted relative to the case on fine pivots located in sapphire

Fig. 1 (below) English Electric Aviation's miniature integrating gyroscope.

Fig. 2 (right) Testing a Mig gyro at Stevenage



bearings. The space between gimbal and case is filled with a damping fluid (Fluorolube), and the weight-to-volume ratio of the gimbal is such that its density is the same as that of the fluid. This means that the gimbal floats within the fluid at neutral buoyancy, neither rising nor falling within its case, the pivot and jewels at either end of the gimbal carrying little or no weight so that friction is extremely small.

The Mig rate-integrating gyro is a single-axis instrument which converts input turning rates into gimbal torques. These are time-integrated by the viscous restraint of the damping gap to give a gimbal displacement;

input rate-of-turn gives a proportional gimbal rate-of-turn, and input displacement gives a gimbal displacement.

Gimbal angular position is picked off by a so-called signal generator located within a 'Dualsyn' at one end of the gimbal. The Dualsyn also incorporates a torque generator of the type one would normally expect to be situated at the other end of the gimbal. This dual arrangement of pick-off and

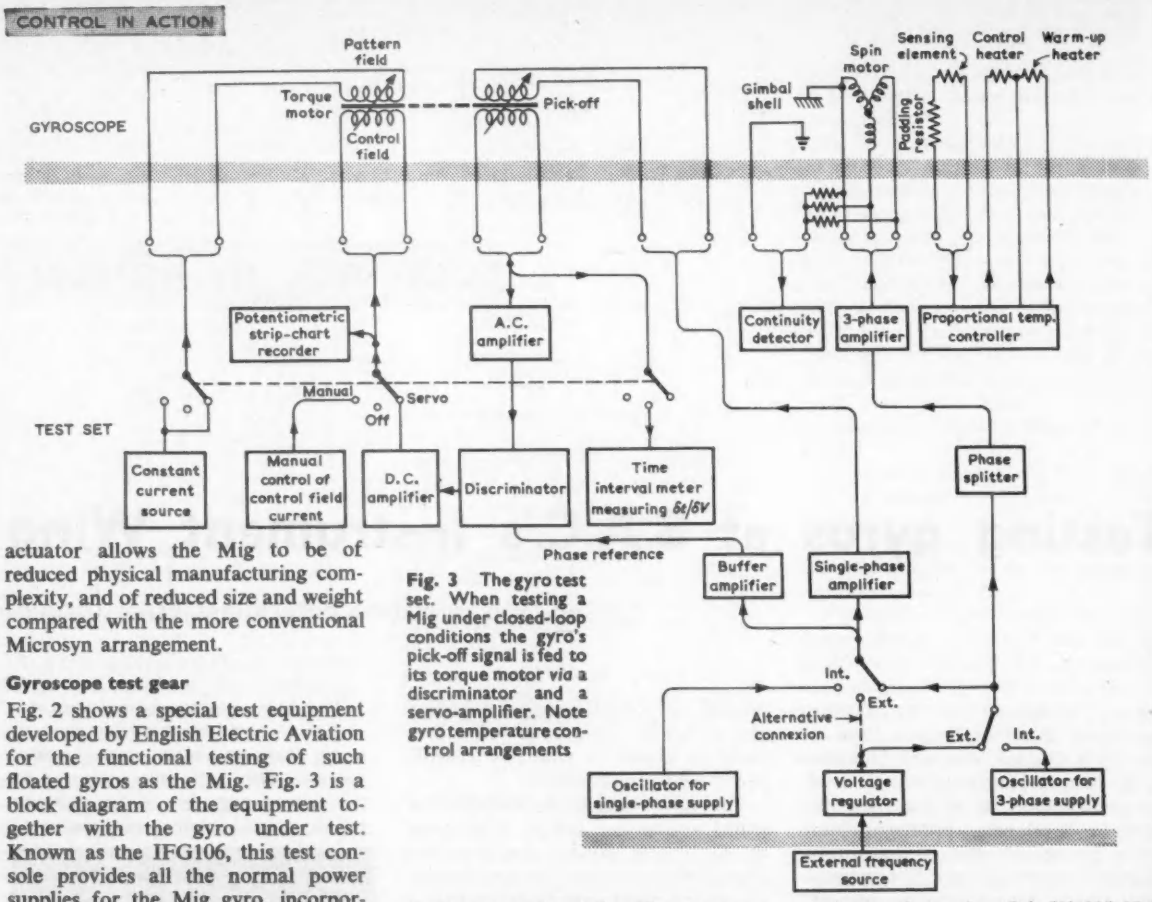


Fig. 3 The gyro test set. When testing a Mig under closed-loop conditions the gyro's pick-off signal is fed to its torque motor *via* a discriminator and a servo-amplifier. Note gyro temperature control arrangements

actuator allows the Mig to be of reduced physical manufacturing complexity, and of reduced size and weight compared with the more conventional Microsyn arrangement.

Gyroscope test gear

Fig. 2 shows a special test equipment developed by English Electric Aviation for the functional testing of such floated gyros as the Mig. Fig. 3 is a block diagram of the equipment together with the gyro under test. Known as the IFG106, this test console provides all the normal power supplies for the Mig gyro, incorporates a valve voltmeter and a potentiometer strip-chart recorder and, as well as permitting such conventional tests as those concerned with leakage currents within the gyro, is capable of closed- and open-loop control and gyroscope temperature control.

A proportional temperature controller automatically maintains the temperature of the gyro at the required level in order to control the viscosity and density of the gimbal damping fluid, and so give the correct gyro transfer function and degree of flotation. The temperature is detected by the resistive sensing element within the Mig and is maintained by varying the power applied to its control heater, the change in power output being proportional to the change in resistance of the sensing element. The temperature controller can apply a quick warm-up, when commencing a test, by supplying extra power to the control heater, the warm-up power being switched off automatically when the resistance of the sensing element reaches the upper limit of its normal working range. The heater supply is automatically cut off if the resistance of the sensing element deviates from its nominal value by more than a predetermined amount, or if the supply to the controller fails. The temperature controller will hold the Mig's temperature to within 0·25 degF of the predetermined level.

Closed-loop control

When testing the gyro under closed-loop conditions, signals from the Mig's pick-off are fed to the gyroscope torque motor (both these units form part of the Dualsyn) *via* a discriminating rectifier and a servo-amplifier, thus automatically restoring the gimbal to the null position. This will be apparent from a study of Fig. 3.

The Mig is operated under closed-loop conditions when it is undergoing the polar-axis tumbling test, a standard method used by the Royal Aircraft Establishment for testing floated gyros. Polar-axis tumbling is used to determine gimbal mass unbalance and the error torques that are due to fixed restraints.

For this test, the gyro is mounted on a motor-driven rotary table in such a fashion that its output axis is accurately parallel to the table's rotational axis. The table is orientated so that its rotational axis is parallel to the axis of the earth, and the table's rotational axis is thus pointing north-south and elevated north by the angle of latitude of the site (51° 53′ 23″ N in the case of Stevenage).

The gyro is rotated at ten times earth's rate but, because its output axis is parallel to the table's rotational axis, it does not sense this rotation as an input rate. Similarly, as its output axis is parallel to the earth's axis it does not sense earth's rate. It follows that the only outputs from the gyro are those due to error torques resulting from mass unbalance of the gimbal, and any restraints due to say the action of the pick-off giving torques to the gimbal.

To determine the error torques, the gyro being operated closed-loop (pick-off to torque motor *via* the servo-amplifier), the torque motor rebalance or control current, which is proportional to the sum of the error torques, is recorded on the strip-chart recorder. The recorded trace is a sine wave having a period of 2·4 h, and of an amplitude proportional to the mass unbalance of the Mig's gimbal multiplied by the cosine of the latitude. The wave-form is displaced from the zero voltage reference line by an amount equivalent to the total gimbal-restraint torque.

Acknowledgement

Thanks are due to E. H. Searle of English Electric Aviation Ltd for help in the preparation of this article.

On-line computer at Fox's

AT THE STOCKBRIDGE STEELWORKS OF Samuel Fox the billet cut-up line is now under the on-line control of a Panellit 609 information system incorporating an Elliott 803 computer. Samuel Fox roll billets up to 450 ft long and these must be cut to suit customers' requirements, with the minimum wastage.

The problem falls into four parts: measuring the length of the billet; calculating optimum cutting points; transmitting this information for display to operators; recording data for office purposes. The computation must be fast enough for billets not to be held up on the track, the length measurement system must be self-calibrating and, since a number of billets can be on the track simultaneously, sufficient capacity for the storage of such information has to be provided. Samuel Fox studied this problem in conjunction with E-A Automation Systems and came to the conclusion that there was ample economic justification for a computer to optimize cutting.

The measurement of length is obtained by a self-calibrating pulse-counting system which compensates for the wear of the mill rolls, and the presence or absence of the billet is detected by lead-sulphide detectors. The customer's order is set-up on a panel controlled by the mill foreman. The computer calculates the optimum cutting points to satisfy the customer's requirements within the mill's operating conditions, and also allows for test pieces as well as making statistical allowances for the variability of the stops at each saw and shear. Information for the operators to use in setting their shears is available within 1s of the billet leaving the mill, although normally these data are stored in the computer until called for. Each operator has a display panel on which information relating to the billet that he is about to cut up is displayed on demand, and checks in the computer ensure that the billet the operator is cutting corresponds with the one displayed.

The system is reported to have been operating satisfactorily since February although sufficient evidence has not yet been obtained to substantiate fully that the expected savings are being realized. However, Samuel Fox engineers appear to be satisfied that these savings will be achieved.

Control at C.E.G.B.'s Elland power station

THE C.E.G.B.'S ELLAND POWER STATION, which was officially opened on 28 April, has an installed capacity of 180 MW, there being three 50 MW turbo-alternators of A.E.I. manufacture. The station is somewhat unusual in that two different makes of boiler have been installed: No. 1 boiler is by Yarrow & Co., and is of the two-drum natural-circulation type giving 550,000 lb/h of steam at a pressure of 950 lbf/in², and 925°F at the boiler stop valve; Nos. 2 and 3 boilers are by John Brown Land Boilers, and of the single-drum natural-circulation type although their outputs and steam conditions are the same as that for No. 1 boiler. All are fired by pulverized fuel but the pulverizing arrangements for No. 1 boiler differ from those for Nos. 2 and 3 boilers.

Each boiler and turbo-alternator combination is controlled as a unit from a control centre, the control scheme having been devised by George Kent Ltd. Units can be operated on 'full automatic' when the quantity of air entering the furnace, the amount of coal being consumed and the steam pressure and temperature are automatically regulated to suit the steam load on the boiler and thus the electrical load on the turbo-alternator.

The control scheme

The Kent control system, which is fairly conventional, maintains the pressure of the steam fed to the turbines at 900 lbf/in² and, with the exception of minor differences, is the same for all three units. A pneumatic three-term control system is used, control being based mainly on the steam/air flow-ratio method, it being accepted that irrespective of the calorific value of the fuel, the air flow necessary for correct combustion is proportional to steam flow.

Fuel

The fuel control system operates to hold the steam pressure constant, any variation in pressure resulting in a corresponding increase or decrease in the amount of fuel supplied to the burners. A Bourdon-tube-operated indicator-controller measures changes in the steam pressure to the turbine, and a pneumatic signal of a value dependent on steam pressure is fed to control the fuelling arrangements. On No. 1 boiler (Yarrow) the control signal operates power cylinders actuating the mill exhauster-motor induction regulators; on Nos. 2 and 3 boilers (John Brown Land) it operates power cylinders for the mill feeder control and pulverized fuel line damper.

Fig. 1 No. 2 unit control board from which No. 2 boiler and its associated turbo-alternator are controlled as a single unit

Combustion air

Draught control is a function of steam flow. Differential tappings in each of the two intake ducts of the forced-draught fans are used to measure the combustion air, and these measurements are averaged in a ring-balance instrument. The steam flow in each of the two mains is also measured, and these signals are added in a

Multelec receiver. Pneumatic outputs from both the ring-balance and Multelec instruments are transmitted *via* a 'ratio-ing' mechanism to a three-term controller. The control signal resulting from these air-steam measurements is employed to operate two power cylinders coupled to the inlet vanes of the forced-draught fans. The combustion air flow is thus decreased or increased in accordance with variations in steam flow.

Combustion-chamber pressure is also automatically controlled, a furnace-pressure controller measuring this and providing a pneumatic signal to control the inlet vanes of the induced draught fans. The furnace-pressure controller thus 'trims' the induced draught so that the pressure within the combustion chamber is maintained at the required level.

Steam temperature

In the case of Nos. 2 and 3 boilers, a thermocouple arrangement at the *outlet* of each secondary superheater provides an average steam-temperature signal to a recorder-controller. This generates a 3–15 lbf/in² control signal, depending upon the deviation from the set point (925°F) and feeds this to adjust the control set point of a second recorder-controller. The latter controller is also fed with temperature signals from thermocouples in the *inlets* to the secondary superheaters.

The second controller provides a 3–15 lbf/in² signal which is paralleled through two differential summators, and is separated by diaphragms into 3–9 lbf/in² and 9–15 lbf/in² signals. The 3–9 lbf/in² signal (such a signal will occur only if the gas dampers—see later—cannot control the steam temperature) is converted to 3–15 lbf/in² and used to control power cylinders operating Hopkinson spray-water regulators on both sides of the boilers.

The 9–15 lbf/in² signal covers the full range of the gas dampers, operating power cylinders for by-pass and main gas dampers. If the steam temperature is below the control range, the main dampers will be fully open, and the by-pass damper closed; if within the control range, the main dampers will be fully open and the by-pass damper gradually opening—when the latter is fully open, the main dampers start to close. If the temperature rises and the dampers are unable to correct this, the control signal will fall into the 3–9 lbf/in² range and bring in the spray regulators.

Yet another controller is employed to hold the temperatures at the outlets of the two superheaters equal. Operating from thermocouples, this third controller has a 100–0–100 degF range and for zero reading (no temperature difference between the two superheater outlets), a 9 lbf/in² signal is generated. This signal is added to each differential summator and balanced against a fixed 9 lbf/in² signal. If, however, the temperature is higher at one outlet than at the other the controller will provide a signal greater or less than 9 lbf/in², a pressure signal which will not balance with the fixed 9 lbf/in² pressure. The outputs from the differential summators will increase or decrease, causing the power cylinders to bring in the Hopkinson spray water regulators. In this way the secondary superheater outlet temperatures will be equalized, and the signal from the controller will balance with the fixed signal.

An entirely different system of steam temperature control is employed on No. 1 boiler (Yarrow). By tilting the burners, the heat distribution in the furnace can be altered and in this way the amount of heat passing through the walls of the superheater tubes can be varied. Automatic spray de-superheaters are also provided. The control of this system is by Superheater Co. Ltd.

Mill control

The fuel pulverizing mills are also controlled. For Nos. 2 and 3 boilers, the suction in the mill inlet ducting is measured, and the resulting control signal is caused to operate power cylinders regulating dampers. In this manner the pressure of the primary air at the inlet to the mills is maintained in spite of any change in the amount of fuel supplied to the burners.

The raw fuel to each mill for No. 1 boiler is controlled to give a balance between the amount of coal fed to the mill and the rate of outgoing pulverized fuel/air mixture. A double-diaphragm controller measures the pressure drop across the mill with the aid of tappings at inlet and outlet, and also the rate of pulverized fuel/air flow with a pitot tube between the mill and the exhauster. The two sections of the controller are connected by a differential linkage coupled to the control mechanism. The resulting pneumatic control signal operates a power cylinder coupled to the induction regulator of the feeder motor.

Instrumentation

In addition to the control arrangements, Kent have also provided a great deal of instrumentation. This includes instruments for measuring and recording steam and feed-water flow, the oxygen content of flue gases, smoke density, and temperatures and draught points throughout the boilers.

Acknowledgement

Thanks are due to George Kent Ltd, from whom much of the material on which this article is based was obtained.

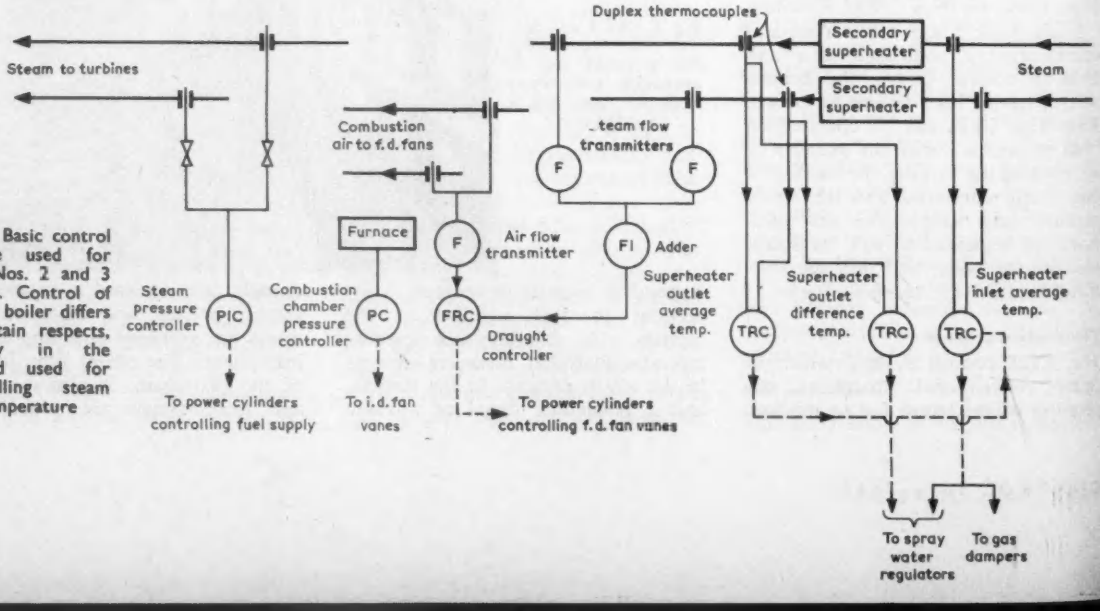


Fig. 2 Basic control scheme used for both Nos. 2 and 3 boilers. Control of No. 1 boiler differs in certain respects, notably in the method used for controlling steam temperature

NEWS ROUND-UP

from the world of control

MACHINING

A.E.I. Symposium

Last month *Control* was privileged to attend a private Symposium on the electronic control of machine tools, at A.E.I.'s Electronic Apparatus Division, Leicester. The Symposium was rather unusual in that all the delegates to it were members of the various companies within the A.E.I. Group, and concerned with the use of machine tools for production, as distinct from control engineering as such.

Four papers were delivered: *Introduction to the electronic control of machine tools* by M. Monk; *Feed drives and tracing controls* by R. Lawson; *Co-ordinate setting as an aid to production* by N. Milne; and *The Numeritrol system of continuous numerical control of machine tools* by D. J. Mynall.

Machine tool control

In his introductory talk, Monk discussed the machine tool mechanism in relation to automatic control. He pointed out that few machine tools were designed specifically with automatic control in mind and that, when one chooses a machine, matters such as size, geometry, manufacturing accuracy required, spindle and slideways dynamics, feed drives, and the possibility of fitting automatic measuring systems should be assessed. He pointed out, for example, that a large machine may not perform so well as a small machine; an automatic machine will be cutting for 70% to 80% of its working life compared with, say, 10% to 30% for a machine under manual control; backlash and power requirements should be reduced by the use of preloading and recirculating-ball leadscrews; independent feed drives for each motion are necessary; and that the fitting of automatic measuring systems may entail large modifications to the machine. He felt that it was usually impracticable to fit automatic control to an existing machine at reasonable cost, although, if the chosen machine is sound, modifications can be incorporated during manufacture.

Lawson discussed the control of feed speed including the conventional Ward Leonard arrangement, and said that where precision, good speed regulation, or a wide range of speeds are required, the best systems use electronic amplifiers and feedback of speed. He described tacho-generator arrangements, thyratron and silicon controlled rectifier controllers and, for high-speed response, electrohydraulic systems.

He also discussed one- two- and three-dimensional tracer systems, and reported that the present tendency was to fit such controls in an attempt to solve special problems rather than to increase productivity.

In his paper, Milne described the A.E.I. system of automatic co-ordinate setting which was first fitted to a Kearns horizontal borer at A.E.I., Rugby, in 1955. This is a punched-card control system. A desired-position signal is obtained from the card, an actual slide-position signal is subtracted from this, and the resulting error signal is applied to the feed drive so that the slide moves in a direction to reduce the error. He gave impressive figures for savings produced by the use of this system.

The Numeritrol system of continuous control (see *Continuous numerical control of machine tools*, by P. S. T. Buckerfield, *Control*, June and July 1960) was the subject of the lecture by Mynall. Briefly, this system controls the position of the cutter with respect to the workpiece in three dimensions simultaneously, operating under the direction of a digital recording on a magnetic tape. These tapes are produced by A.E.I., Leicester, from information provided in the form of a planning sheet by the user. This data is transferred to punched paper tape (Tape A), fed to a Ferranti Pegasus computer, where profile information is combined with tool diameter, and the resulting Tape B is then fed to the Numeritrol Director which produces the final magnetic recording.

After the lectures, the party toured A.E.I.'s New Parks Works, seeing a Numeritrol machine in action, and the Blackbird Road factory for a demonstration of Newall Spacematic jig borers. One of the latter was producing precision cams by 'staircase milling' under punched-card control, the final product requiring no further finishing. This was a very impressive but rather long-winded process requiring about 140 minutes per cam; this compares with about one-third, or less, time by the Numeritrol continuous system.

How much?

A lively discussion followed. Obviously the delegates were impressed, but they appeared to feel that automatic control was concerned with special problems, rather than with the more down-to-earth difficulties of the

TRACING THE ROUTE This routing machine by Cramic Engineering, and used by them for the copy-milling of light alloy components, is fitted with an electronic two-dimensional tracer control by A.E.I. The stylus presses so lightly against the template that the latter may be of fairly soft material and less complex than usual. Note that in addition to copying facilities, the control station is fitted with joystick control giving independent variable feed-speed control and steering control.

production engineer. Several speakers queried costs, one saying that a controlled machine might cost four times the price of a manual machine. This figure was thought by the panel to be extreme, their figure being nearer 2:1 than 4:1. Others pointed out that auto-control would mean higher planning costs, and there was some criticism of the fact that highly skilled operators were being used on auto-controlled machines. Maintenance and reliability were other subjects raised from the floor, but the panel assured us that the systems were reliable and that a good maintenance service was available.

To the question: how much are the tapes? the reply was £7 10s 0d per computing hour—assuming that the planning was done by the user.

Several speakers were doubtful about justifying the expense of an automatic system, and demanded a better breakdown of costs. The panel pointed out that there was a saving in jigs, and that inspection was unnecessary once a tape had been proved. There was some suggestion that an automatic system was warranted for difficult work only, but this was denied, it being claimed that the future for reducing costs lay with making fewer components but of greater complexity.

The discussion also brought out the fact that the A.E.I. Electronic Apparatus Division are working on an automatic control system for machine tools which will be comparatively inexpensive and of general application.

BEDFORD ROCK This rocking cockpit, or 'flight simulator moving cockpit mechanism' has been built by Short Bros for R.A.E., Bedford. Fitted with a fully-equipped cockpit and with an analogue computer feeding in disturbances, it will be used to test a pilot's ability to control a high-performance aircraft under difficult flying conditions. Powered by two electrohydraulic servos, the cockpit can be rolled $\pm 15°$ at up to 45°/s, and can pitch 20° above the horizontal, or 10° below, at up to 25°/s.

BUSINESS

Ultra's intentions?

Ultra Electric obviously intend to divest themselves of any contact with the domestic market. Last month we reported their sale of a 40% share in Ultra Electronics to Electronics International Capital Ltd, an American concern based on Bermuda, and the agreement to exchange information between Ultra Electronics and Electronics Investment Management Corp., U.S.A. Now, Ultra Electric have sold their domestic radio and television interest to Thorn Electrical for £2·4m.

According to Ultra, the monies received from the sale to Thorn 'will be used to relieve pressure on liquid resources and will also be sufficient to meet the demands of expansion in the electronics industry'. Ultra Electronics already have the right to borrow up to £2,075,000 (from Electronics International Capital and Ultra Electric), and there should be little shortage of capital for expansion. The question is: where do Ultra Electronics go from here? They have already acquired Trix Electronics, the sound amplification firm. However, there is little doubt that they will make a determined attack on the control and instrumentation market.

ELECTRICITY

More on West Thurrock

As reported in these columns in March, Babcock & Wilcox are to employ a Ferranti Argus digital automatic control system for the automatic start-up and shut-down of a 200 MW boiler in the C.E.G.B.'s new power station at West Thurrock. Now Evershed & Vignoles have released some details of their participation in the control scheme for the station.

The whole of the boiler–turbine unit is covered by a main control loop which relates electrical output as a control criterion to the fuel input to the boilers. A measurement transducer generates a signal proportional to the load, and this forms the main input variable to three on-line analogue computers of simple type; each computer also receives one input signal representing master pressure, air/steam ratio, and furnace pressure respectively. The computers process the signals continuously and instantaneously, and their output signals, after passing through subsequent stages of the control loop, regulate the operation of the mills and of the forced- and induced-draught fans.

The Ferranti Argus digital process control computer will carry out the overall automatic control of the unit during start-up and shut-down by generating a resetting signal for the set points of the Evershed analogue process controllers. This has necessitated transmitters of wide measurement range (covering, say, from zero to full working pressure) which, when normal operating conditions are reached, are automatically replaced by sensitive transmitters covering the normal working range only. Once the station load and boiler operation have reached normal level, control is effected continuously by three-term process controllers.

SPACE

America's manned firing

At 9.34 a.m. (U.S. E.S.T.) on 5 May a Redstone rocket carrying a capsule *Freedom 7* with, as passenger, Commander Alan B. Shepard, U.S. Navy, was launched from Cape Canaveral. The capsule separated from the rocket 2½ min later, and an autopilot controlled the attitude jets to swing the capsule round and bring the heat shield forward. At about 9.37 a.m., Shephard operated the attitude jets manually, making the capsule perform some slight manouevres in pitch, yaw and roll—the trajectory of the capsule was not, of course, under the control of the astronaut. Apogee (115 miles) was reached at around 9.39 a.m., the retro-rockets were fired and, two minutes later, the retro-package was jettisoned. Re-entry commenced at 9.42 a.m., and the capsule parachuted into the sea, 302 miles from the launching point, at about 9.49 a.m.

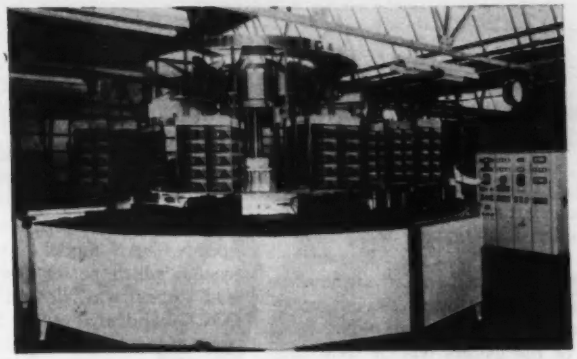
A magnificent technological achievement, this enabled a brave man to become the United States' first 'astronaut'. A fifteen-minute firing, it can not, of course, be compared with the orbit of the Russian, Flight Major Gagarin, in *Vostok* on 12 April (see these columns, last month), but the fact that it was carried out in the full glare of publicity, shows great faith in the reliability of the rocket, capsule, instrumentation and passenger.

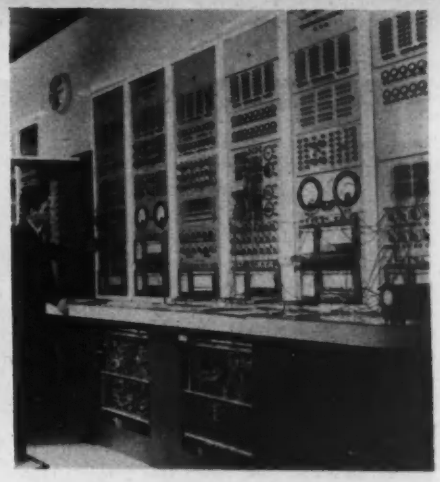
DATA PROCESSING

Honeywell's d.p. division

The Electronic Data Processing Division set up last month by Honeywell Controls, will introduce two of Minneapolis-Honeywell Regulator's range of computers to this country, the '400' and '800' machines. It appears that the company's production facilities at Boston, U.S.A., have been greatly increased and that they can now deliver within fifteen months.

PACE SIMULATES SPACE Built under a $1.5m contract from the U.S. National Aeronautics and Space Administration, the world's largest analogue computer undergoes final inspection at Electronic Associates Inc. Intended for N.A.S.A.'s Langley Field, where it will be employed in the simulation of satellite and space vehicle programs, the machine comprises five separate Pace computers and has 1500 high-speed computing units, including 800 amplifiers.





SATURN STUDIES STABILITY The largest analogue computer in Europe, Saturn, which was built by English Electric at a cost of £300,000 in order that such problems as nuclear reactor instability can be studied. Consisting of six units, each containing 252 amplifiers, Saturn is in use at Whetstone working on the problems of the Hinkley Point nuclear power station being built by the English Electric-Babcock & Wilcox-Taylor Woodrow group.

PRINTED-CIRCUIT REVOLUTION A.E.I. claim that this automatic etching plant at the Boreham Wood factory of Printed Circuits Ltd (an A.E.I. company) is the most modern of its type in the world. The plant is program-controlled, all human handling during processing being eliminated. The process includes cleaning and degreasing operations before and after processing. Printed Circuits Ltd occupies the same premises as Millett, Levens Ltd, known principally as manufacturers of metallic name plates. Much of the equipment in the combined factory is adaptable for production of either printed circuits or name plates.

The Honeywell 800 is a medium-to-large machine costing around £395,000 (monthly rental: £8500), and is said to be the only computer yet developed that is capable of performing up to eight independent operations simultaneously. Of modular design, allowing practically unlimited expansion, the 800 has 'orthotronic' control—automatic detection and correction of errors, and its speed is 40,000 three-address operations per second.

The 400 computer is a smaller version of the 800, being a magnetic-tape data-processing system developed for the smaller organization. Honeywell feel that this machine should attract those who would like a magnetic tape system, but, heretofore, have been unable to afford one. Honeywell claim that the 400, which costs £139,000 (monthly rental: £3090), gives both magnetic tape and card processing at the cost of a card system alone.

American Honeywell will deliver over £17m worth of computer systems to U.S. customers during 1961.

It is understood that eventually both machines will be manufactured in this country, the parts being made in the Honeywell factories in Newhouse and Hemel Hempstead.

RESEARCH

N.P.L. on show

Open days at the N.P.L. last month had their usual air of reality and informality. The 'Autonomics' Division—until last year the Control Mechanisms and Electronics Division—is going ahead with its researches into adaptive control and high-speed computing. The immediate aims in adaptive control are directed at the distillation column pilot plant at the Warren Spring Laboratory (another D.S.I.R. research establishment). Longer term thoughts in this division are largely concerned with the biological/electromechanical analogy, particularly in connexion with mechanical reading and translation. The N.P.L. has been working on these problems for some time, but is now stepping up its researches on the biological side. The object is to find out the nature of the mechanism which permits the living physical system to recognize given characters, though these may be written or printed in a variety of styles.

Research into high-speed computing has been centred on cryotron development, and circuits containing up to twelve cryotrons on a single plate, have been made.

In the Standards Division, much attention is now being given to pneumatic gauging techniques. A gauge has been developed for accurate diametrical measurements, using feelers and air-nozzles at the two ends of the diameter simultaneously. The object of this arrangement is to avoid the error caused in conventional gauges (where the specimen rests on a flat surface and one air-nozzle detects the position of the highest point) by distortion of the specimen. Automatic aids for speeding up inspection are also receiving attention. An automatic machine for inspecting slip gauges, using a pneumatic comparator technique, is at an advanced stage of development. The accuracy is expected to be $\pm 1\mu$in.

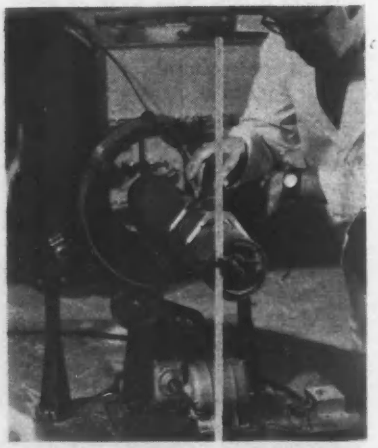
B.I.C.C.'s new laboratory

The McFadzean Laboratory of British Insulated Callender's Cables, which was officially opened by the Duke of Edinburgh on 16 May, was visited by *Control* last month. The Laboratory is part of the B.I.C.C. research organization at Wood Lane in west London, and exists to carry out

long-range experimental work for the engineering laboratories which form part of every production unit.

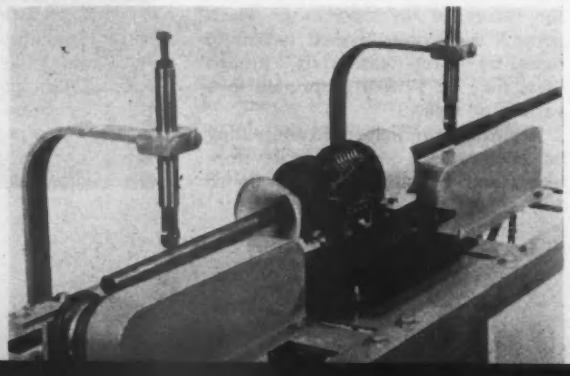
Naturally enough, *Control* was most interested in the Instrumentation and Control Department. Here measuring devices, mainly for use in the various B.I.C.C. factories in non-destructive quality-control testing, are developed, complete instrumentation schemes are designed and constructed, and automatic production equipment is devised. Non-destructive testing arrangements were much to the fore. These included the low-energy d.c. spark-testing of cable insulation with the output of the equipment being given by a new paper-tape recording device. Electromagnetic methods of quality control in the manufacture of wires and metallic tubes were shown, the latter being tested by the eddy current methods also used by the British Non-Ferrous Metals Research Association—see below. A continuously-operating eddy-current gauge, now in its final development stage, was demonstrated operating on a length of pipeline (see illustration).

A demonstration wire-processing line was of particular control engineering interest. This incorporated several devices facilitating the transport of wire through the various cable-making processes and to control quality. For example, the take-off from the reel at the beginning of the line passed *via* an induction braking motor which was controlled from the far end of the line to hold the wire tension constant.



Above. Measuring head of the continuous lead-sheath gauge, an eddy-current tester, at B.I.C.C.'s McFadzean Laboratory

Right. Prototype coil assembly at the B.N.F. for eddy-current testing of tubes



NEWS BRIEFS

Satellite communications are being discussed between representatives of the Post Office, S.B.A.C., British Constructional Steelwork Association, E.E.A., B.E.A.M.A., R.I.C., and T.E.M.A.

Optical instruments: Hilger and Watts report that Wray (Optical Works) Ltd have come into association with them, and that A. W. Smith is continuing as Managing Director of that company.

Solenoids in the Soreng range by the Controls Co. of America are to be manufactured here by Westool Ltd.

Document handling equipment is the subject of a long-term marketing and manufacturing agreement between I.C.T. and the National Data Processing Corp., Dallas, Texas, U.S.A.

Postgraduate diploma course in automatic control will be held from 2 October at Northampton C.A.T., under G. M. E. Williams (Head of Department) L. Finkelstein, B. Girling and J. C. Williams (Lecturers). Details: Head of Department, Department of Production Technology and Control Engineering, Northampton College of Advanced Technology, St John Street, London, E.C.1.

Mathematics of automatic control: A Summer School is being held at Hatfield Technical College, 26–30 June, 1961. Details: J. A. P. Hall, Head of Mathematics Department, The College, Hatfield, Herts.

Burroughs Machines Ltd is the new name for Burroughs Adding Machine, a change intended to be more representative of the firm's range of data-processing products.

METALS

Thickness gauges for Russia

Davy and United Instruments are to supply Stankoimport of Moscow with eight transmission gamma-ray thickness gauges for installation in Russian steel mills. These gauges use a radio-active isotope as the measuring medium and are capable of automatic continuous and accurate measurement without touching the material.

One of the gauges will be used for measuring hot steel plate between 3·75 mm and 50 mm thick; another will be on a hot-strip mill measuring hot rolled strip between 1·5 mm and 12·5 mm thick. The remaining six gauges will be installed on cold-strip mills and will be measuring strip between 1·5 mm and 12·5 mm thick.

The radio-active sources and detection devices are being supplied by Isotope Developments.

The value of the contract is believed to exceed £90,000.

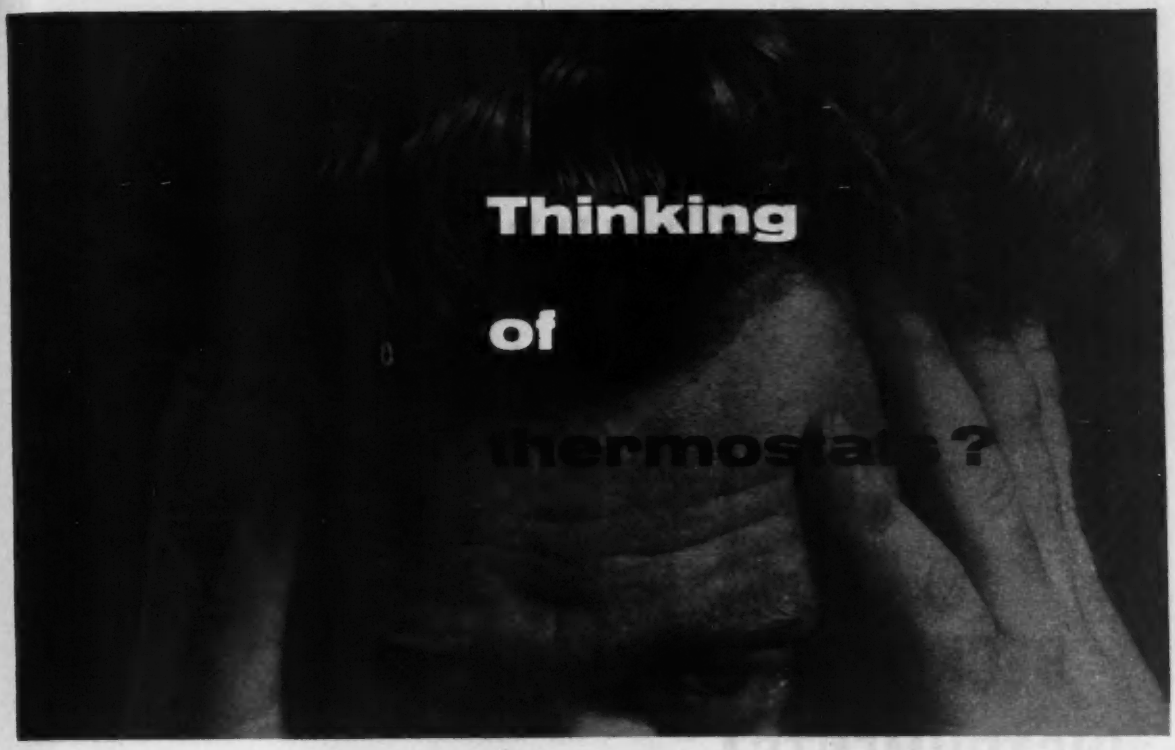
Auto-testing at B.N.F.

During a recent visit to the British Non-Ferrous Metals Research Association *Control* saw something of the Association's work in the instrumentation and control fields.

The B.N.F. are continuing their work on automatic tube-testing by the eddy current method. Many specifications for copper alloy tubes call for the tubes to be hydraulically tested—a laborious time-consuming process. The use of eddy currents to detect cracks and manufacturing faults in tubes is not only more sensitive than hydraulic testing but it permits inspection to be carried out automatically at high speeds. A model auto-inspection system which passes good but rejects bad tubes was demonstrated. The B.N.F. said that such a continuous inspection system was already in use, but felt unable to say who was using it. However, *Control* visited B.I.C.C.'s new McFadzean Laboratory a few days later—see above—and found B.I.C.C. willing to claim that honour.

Conveyor control

The Electronics Division of Bruce Peebles, Edinburgh, have received an order from the Head Wrightson Machine Co. for an electronic control system for overhead magnetic conveyors on the steel strip cut-up lines at the Spencer Works of Richard Thomas and Baldwin. This largely static control system will employ silicon controlled rectifiers and solid-state circuits to control, automatically and in the correct sequence, the excitation supplies to sections of electromagnets in the overhead conveyor lines. Each of these lines will form part of the classifier section of a side-trim and cut-up line which handles steel strip 0·02 in to 0·10 in thick in widths up to 5 ft and at speeds of up to 960 ft/min. The classification will be entirely automatic, each sheet being released from the conveyor onto either a 'prime' or a 'reject' pile by switching the excitation of the appropriate magnet in response to the output of a classifier unit. The latter interprets signals from separate sheet-inspection equipment.



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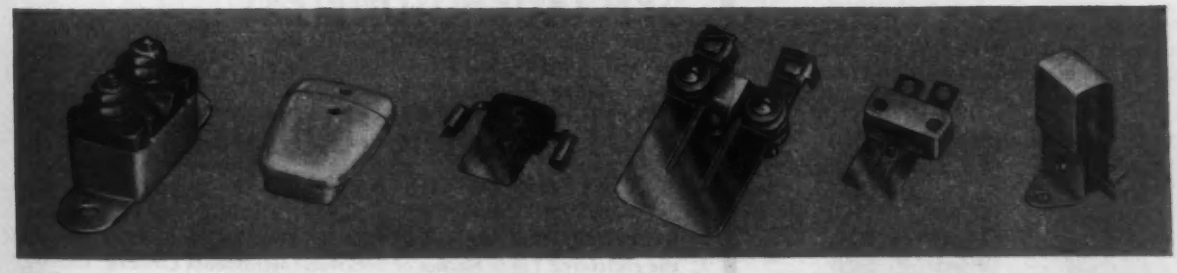

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PEOPLE IN CONTROL

by Staffman

FOXWELL GERTSCH
contract bridge

A reciprocal sales and manufacturing arrangement has been established between Wayne Kerr Laboratories and Gertsch Products Inc. of Los Angeles, U.S.A. I understand that the idea is for Wayne Kerr to market and manufacture certain Gertsch electronic instruments in the U.K.—precision ratio transformers, frequency measuring equipment, synchro and resolver standards and test instruments—while Gertsch will market such Wayne Kerr products as the transfer function computer, transformer ratio arm bridges and so on, in California, Nevada and Arizona. My photograph shows **Elmer P. Gertsch**, President of the Los Angeles firm, and **R. Foxwell**, Managing Director of Wayne Kerr, signing the agreement on 16 May.

The British Electrical and Allied Manufacturers' Association—Beama—have a new office in their Council for 1961/62, that of Counsellor. The President for the year is **A. M. Browne** of Hackbridge & Hewittic, the Deputy-president is **H. H. Mullens** of Reyrolle and the Counsellors are Lord **Chandos** (A.E.I.), Lord **Nelson of Stafford** (English Electric), Sir **Vincent de Ferranti** (Ferranti), **W. K. G. Allen** (W. H. Allen Sons & Co.), and **J. O. Knowles** (Metal Industries).

Beama, incidentally, have set up two new Sections, the Industrial Electronic Equipment Section, and the Nuclear Reactor Section. In addition to day-to-day work relating to technical matters, standardization, exports and statistics, the Electronics Section will provide a means for discussion with other associations, and is expected to help towards the wider examination of general policy questions affecting the industrial electronics industry as a whole. **W. Gregson** of Ferranti is Chairman, and **R. J. F. Howard** of Metal Industries, Vice-chairman.

The A.G.M. of the Society of Instrument Technology took place on 23 May, and was attended by many well-known personalities in the control and instrumentation fields. Four Ordinary Members of the S.I.T.'s Council retired, **E. B. Jones** (Associated Ethyl), **D. C. Nutting** (British Hydrocarbon Chemicals), **H. J. Smith** (Industrial Pyrometer), and Professor **G. D. S. MacLellan** (University of Glasgow); two, Dr **H. H. Rosenbrock** (Automatic Control Engineering) and **D. S. Townend** (B.P.) resigned. Consequently there were six vacancies, and elected to fill these were **T. P. Gray** (I.C.I.), **J. M. Keating** (B.P.), **R. J. Redding** (Evershed & Vignoles), **J. F. M. Scholes** (I.C.T.), **A. Stewart** (I.C.I.) and Professor **J. C. West** (Queen's University of Belfast).

The new President is to be **S. W. J. Wallis** (B.P.) and, the rules having been changed in order to allow the Society to have four instead of two Vice-presidents, Professor MacLellan, **L. B. Lambert** (Negretti & Zambra), Dr Rosenbrock and **S. S. Carlisle** (Bisra) were elected to fill that office. Lambert was, of course, Hon. Sec. and, his election as Vice-president having left that position vacant, H. J. Smith agreed to take the post. Both Carlisle and Redding have other duties as well, being Chairman and Vice-chairman, respectively, of the S.I.T.'s Control Section.

After the A.G.M. the President of the Society, **G. C. Ellenton** (Shell Refining)—he, of course, becomes Immediate Past President—delivered his Presidential Address *Our technology and society*. He gave some rather distressing figures for the growth of instrumentation and control in Britain, and said: 'Visitors to the I.S.A. exhibition in the U.S.A., to the Interkama exhibition in Germany, and to the I.F.A.C. conference in Moscow, have almost unanimously reported that in these countries automation is taken more seriously and is progressing faster than in this country.' He saw the problem as one of educating and training the technologist.

I see that **J. N. Toothill**, a director of Ferranti and General Manager of Ferranti, Edinburgh, has been awarded an Honorary Companionship of The Royal Aeronautical Society, although the award itself will not be presented until September. A Governor and Deputy-chairman of the College of Aeronautics, Toothill is well known to control engineers. His *Viewpoint* in February 1960 aroused a great deal of interest for he had strong things to say about the economics of developing new products. I seem to recall his telling me some years ago that Ferranti had spent over £0·5m on machine-tool control and had little hope of seeing a decent return on their money. Another R.Ae.S. award, the Wakefield Gold Medal, goes to Dr **E. Eastwood**, Marconi's Director of Research 'for his contribution towards safety by the development of air traffic control and navigational aids.'

STANLEY
fellow

TOOTHILL
companion

Still on the subject of awards: I was rather amused to learn that **C. O. Stanley**, Chairman of Pye, and a man whose prime interest seems to be in keeping the radio industry on its toes, has been col-

lecting academic honours. Recently he received an honorary Doctorate from Trinity College, Dublin, and now he has been awarded a Fellowship of the City and Guilds of London Institute in recognition of his 'professional status and achievements'.

I was most surprised to learn that **Robert Broadbent** is no longer Managing Director of Sperry Gyroscope, although still a member of the Board. It appears that he is being replaced by **Robert G. Hess** who is President of the (American) Wright Machinery Co.—a Division of Sperry Rand Corp. According to Sperry, Brentford, the appointment of Hess is a temporary measure intended to strengthen the direct co-operation between the American and British companies and to achieve efficiency and

HESS
co-operator

STEVENSON
salesman

competitiveness in export markets. As over half British Sperry's output is exported already, it looks as if somebody is worried about the Common Market. I gather that Hess will return to the U.S.A 'as soon as his assignment has been satisfactorily completed'.

Incidentally, **J. D. Stevenson** has been appointed Manager Aero Sales at Brentford, in succession to **C. A. Richardson**, who went to Sperry Europe Continental, Paris, recently, as Director of Export Sales. Stevenson became Assistant Manager Aero Sales in 1958, and previously was for eight years Manager Aero Sales of Sperry Gyroscope of Canada.

I see that Creed's Managing Director, Group Captain **F. C. Daubney** has been elected Chairman, a position which has been vacant since the death of Sir **Francis Brake** a year ago. Daubney joined Creed, the Croydon telegraph and data-processing firm, in 1949. The following year he became Commercial Manager and later General Manager. He was appointed Managing Director in May 1957. Other Creed news includes the election of **F. W. Helmer** to the Board after 42 years with the company.

AUTHORS IN CONTROL

Eric H. Jones (*Automatic control of impregnating and coating processes*, page 84) has been engaged in textile research since 1922. He is the author of numerous papers and articles relating chiefly to research and development work in the processes of yarn preparation, sizing and weaving. Among the developments for

JONES

which he has been responsible are a moisture meter for textile materials, automatic moisture-controlling equipment, a method of accelerating cylinder-drying, and automatic systems for controlling the application of impregnating and coating substances in continuous processing. His present position is that of Principal Research Officer in the Weaving Department of the Cotton Silk and Man-made Fibres Research Association stationed at the Shirley Institute. He was elected a Fellow of the Textile Institute in 1944 and a Fellow of the Institute of Physics in 1950.

A. J. Wakefield (*Operating a power station with a computer*, page 88). See page 129, May 1961.

J. H. Westcott (*Adaptive control*, page 92). See page 129, May 1961.

J. W. W. Shaw (*Supply and regulation of boiler feed-water*, page 94). See page 129, May 1961.

P. F. Blackman (*Pole-zero approach to system analysis*, page 98). See page 126, November 1960.

Anthony Clark (*Null-balance differential radiation detector*, page 107) joined the Distillers Company Research Department, Epsom, after a brief foray into publishing and post-war service in the R.A.F. He is now an assistant physicist at Distillers where he specializes in the development of fine assemblies. According to Clark, he is more distinguished as an archaeologist than as a scientist, but too enamoured of science to give it up. He is interested in the application of physical methods in archaeology, and was one of the designers of a highly successful electronic soil-resistivity meter for detecting buried remains. A Fellow of the Society of Antiquaries of London, he claims that his darkest secret is that he tried to get a part-time physics degree at Birkbeck College, but gave up the struggle in the face of competing interests and, he says, mental limitations.

M. A. Beechey (*Practical methods of tuning process control loops*, page 111) graduated from Imperial College, London, in mechanical engineering in 1944. He then served for two years in the Fleet Air Arm as an air engineer officer. He joined George Kent Ltd in 1948 and spent ten years in that company's Research and Development Department working on the application of automatic control in the steel and power plant industries, before transferring to the Sales Department as Control Applications Engineer. He left George Kent in order to take up an appointment as Sales Engineer with Audco Controls in 1960. Quite recently he joined the headquarters of the Central Electricity Generating Board as Assistant Engineer (Control) in the Power Plant Design Branch. Beechey is particularly interested in automatic boiler control.

Ludwik Finkelstein (*Foreign-language periodicals*, page 115) was educated at the Northern Polytechnic (University of London) where he read physics and graduated in 1951 with the degrees of B.Sc. (General) in pure mathematics, applied mathematics and physics and that of B.Sc. (Special) in physics. After a year on the technical staff of Electronic Tubes Ltd, he joined the Mining Re-

BEECHEY

FINKELSTEIN

search Establishment of the National Coal Board where he was concerned with the applications of instrumentation in mining. In December 1959, Finkelstein was appointed Lecturer in Measurement and Automatic Control at the Northampton College of Advanced Technology, London. Recently he became Senior Lecturer in Measurement and Instrumentation. An A.Inst.P., he took his M.Sc., at the Chelsea College of Science and Technology.

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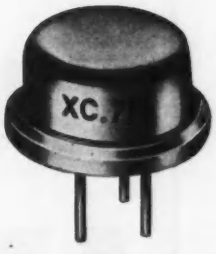

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pressure limit 10,000 lbf/in²

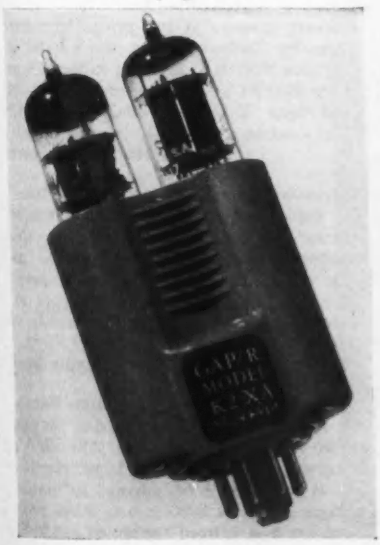
Coutant Electronics' CP.12 transducer has a pressure range from 0–8000 lbf/in² with an output of 1 V (open circuit) at 5000 lbf/in² for a supply of 40 V. It will withstand pressures up to 10,000 lbf/in² without damage or need for resetting. Maximum operating temperature is 85°C (special model 105°C), and stainless steel construction allows satisfactory operation in most corrosive media. Terminal linearity is 1·5%, and hysteresis is 0·25%. Frequency response: output is linear up to 5000 c/s. Circle **No 555** on reply card

DIFFERENTIAL AMPLIFIER

low drift-rate

The Philbrick (U.S.A.) octal-based differential amplifier, the K2-XA, is intended for analogue computer and instrument applications. Typical d.c. open-loop gain is given as 30,000, and when operated as a unity-gain amplifier the band-pass is 250 kc/s. Output impedance at low frequencies is 0·2 Ω, and the amplifier will deliver up to 3 mA at ±100 V.

Octal plug-in base



Power requirements are 0·75 A at 6·3 V a.c. or d.c., and 14 mA (maximum) at ±300 V d.c. Overall dimensions (above chassis) are 1½ × 2½ × 4½ in; weight is 3 ounces. Circle **No 556** on reply card

POWER SUPPLY

electronically stabilized

Allied Electronic's EV451-A d.c. power supply provides three outputs: 0–300V, 50mA d.c.; 200V, 20mA d.c.; and 6·3V, 3A a.c. Characteristics of the two d.c. supplies are as follows: stability of voltage about set point, ±0·015% for mains variations of ± 10% and output variations from zero to full load; internal resistance, less than 0·25 Ω, and internal impedance less than 2 Ω up to 50kc/s. The d.c. supplies are isolated from earth, the variable supply being positive, and the fixed supply being negative with respect to a common terminal. Thus the two may be used to give ±500V d.c. at up to 20mA. A voltmeter and ammeter are permanently connected in the variable supply.

Circle **No 562** on reply card

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Keelavite's K.G. valves are intended mainly for protecting units in a hydraulic circuit against excessive pressure, and the drive unit from overload. The range includes four types: two relief-valves–the CO, for small flows or use as a pilot valve, and the BVL, for use as a main relief-valve, which is suitable for remote operation; the BVDCR off-loading or bypass valve, which incorporates a non-return valve and may be used for automatic pressure unloading; and the DR double-relief-valve, for use in circuits using two pump-pressures.

The operating mechanisms of all four types are made from specially hardened steel, with bodies and end-covers of forged steel. Various models cover maximum pressures from 550 to 7000 lbf/in².

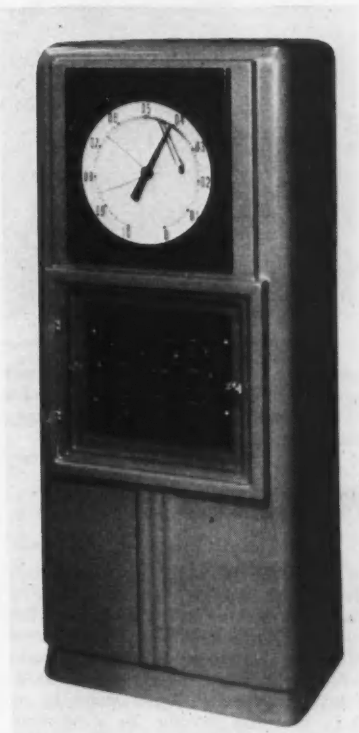
Circle **No 565** on reply card

RESIDUAL CHLORINE CONTROLLER

automatic operation

A recorder/controller by Wallace and Tiernan is available in the following ranges: 0–1, 0–2, 0–5, 0–10 and 0–20 parts/10⁶. Standard charts cover a 24 h cycle, and 'high' and 'low' adjustable contacts may be fitted for operating alarms. Quantity of water passing through the measuring cell is about 5 gal/h, the minimum pressure required being 10 lbf/in². Indicated residual chlorine content is compared with required residual chlorine content, and if there is any difference between them the controller is energized and the dosage is changed proportionally to that difference, whether the deviation is due to changes in flow or quality.

If flow variations are large, the time interval between the injection and sampling points also varies widely. This controller can accept a signal from a flowmeter operating from an orifice plate



Compensates for changing flow

or venturi, which permits it to alter the process time delay in accordance with the flow change and so maintain optimum working.

Circle **No 561** on reply card

TRANSISTOR SWITCHES

standard 19 in chassis

A range of transistor switching-equipment by Bruce Peebles is designed to replace conventional mechanical limit-switches. The operation of the system is based on the variation in inductance of the detector head with the approach of a ferrous body, the change in inductance throwing a bridge network out of balance. The output from the bridge is fed to a transistor switching-amplifier, which in turn can control valve actua-

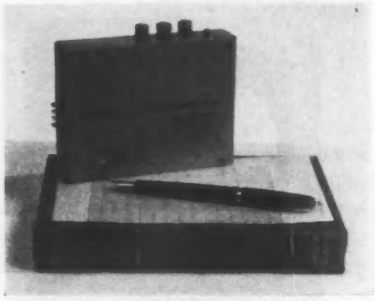
tors, contactors etc. The type 155 detector head has a maximum detecting range of ¼in, and will operate at temperatures up to 100°C. Power units are available, the required mains input for which is 110–230V (nominal), at 50c/s.

Circle **No 563** on reply card

COMPUTING AMPLIFIER

chopper stabilized

A transistorized computing amplifier by Fenlow Electronics has a d.c. gain of $1{\cdot}4 \times 10^6$, and a gain above 200 c/s of 2×10^3. Bandwidth is 1·5 kc/s, and drift is typically less than 100 V/day; temperature coefficient is 5 V/deg C. Input impedance is 100 kΩ and output voltage swing is ± 10 V into 1000 Ω. Noise at



Low noise

output is less than 100 μV. Power supplies for this compact amplifier are ±12 V and − 12 V d.c., with a consumption of 100 mA.

Circle **No 569** on reply card

PROXIMITY CONTROL UNIT

senses non-ferrous metal

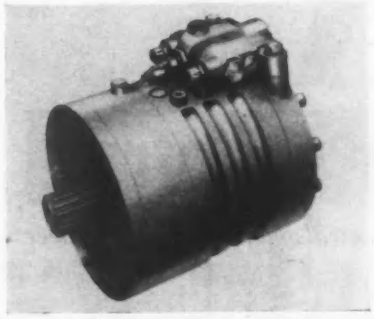
Model 4906–JIC, made by Electro Products Laboratories (U.S.A.), uses a proximity pick-up which senses both ferrous and non-ferrous metal. Two forms of delay are provided, slow-make quick-break, and quick-make slow-break: the former allows metal to remain near the detector for a predetermined time before the control relay closes, but the relay is de-energized immediately the metal is removed; in the second form of operation, the relay is energized immediately there is metal near the detector, and remains so whilst the metal is there and for a further preset delay time. The slow-make quick-break facility is useful for automatic parts feeders, since the unit will operate only if there is a 'pile-up' of parts in the vicinity of the detector.

Circle **No 564** on reply card

HYDRAULIC ACTUATOR

semi-rotary action

Made by Dowty Hydraulics is a single-vane unit with a maximum operating pressure of 1000 lbf/in²: starting torque at this pressure is about 2200 lb ft, and dynamic torque about 2800 lb ft. Usable angular movement is 200°, and external



Usable angular movement 200°

travel-limiting stops are fitted. Provision is made for a relief valve to be manifold-mounted on the unit.

Circle **No 559** on reply card

TWIN POWER SUPPLY

24V and 12V outputs

A power-supply sub-unit by Microcell, costing £30, is intended for use where a high degree of stabilization is not required. Output voltages are 24V ± 2V and 12V ± 1V, each at 0 to 1A; stabilities for a ±10% mains variation with a load of 1A are ±4% and ±2% respectively. In either case output impedance is less than 0·5 Ω from d.c. to 20kc/s, ripple at 1A is less than 10mV peak to peak, and maximum operating temperature is 40°C. Power supply required is 200–250V at 40–60c/s.

Circle **No 568** on reply card

ELECTRONIC MODULATOR

low-level d.c. chopper

Modulator SM 10, by Bailey Meters and Controls, is a small silicon-transistor chopper for low-level d.c. chopping. A built-in wave-shaping circuit will operate from any 6 V sinusoidal or square-wave supply from 40c/s to 1000c/s, and

Wide temperature range

will switch a range of chopping voltages from 1V to 250mV. Output voltage is claimed to be within 1% of the input voltage.

Operating temperature range is 0–55°C, the output temperature-coefficient being 1μV/degC average to 2μV/degC maximum. The SM 10, which plugs into a standard B9A valve-holder, is to be marketed by T.M.C.

Circle **No 567** on reply card

SOLENOID VALVE

pressures up to 1000 lbf/in²

The Skinner V10 series of solenoid hydraulic valves, available from British Arca, has been augmented by the addition of a dual-purpose three-way valve, known as the V18. It is suitable for pressures up to 1000 lbf/in². Body and internals are made from stainless steel, with an orifice equivalent to 3/32in diameter. Coil consumption, for a.c., is 10W. These valves are available with explosion-proof housings.

Circle **No 566** on reply card

QUICK LOOKS

Analogue computers. Redifon's Radic computer is designed for educational use in technical colleges and universities. Unit construction is used, the basis of the design being a module of ten operational amplifiers which can be expanded to twenty if necessary. Alternatively, the same cabinet (43 × 33 × 24 in) can house fourteen amplifiers, the remaining space being used for such elements as servo multipliers The amplifiers can be used with resistors for arithmetic functions, or with capacitors for integration.

Circle **No 551** on reply card

Solenoid valve. Industrial Pneumatics' Capsula valves are available in o.d. pipe sizes 5/32, 5/16 and ¼ in. They can be supplied for most voltages, either a.c. or d.c.; for a.c. operation, inrush current is 28 mA, and hold-on current 18 mA.

Circle **No 552** on reply card

Pressure gauges. A low-priced pressure gauge by Buchanan Bros, the Clyde, is available with B.S. pressure ranges from 60 to 600 lbf/in². Instruments now in production have 4 in dials—2 in and 2½ in models will shortly be available.

Circle **No 546** on reply card

Valves which can be serviced 'in-line' are made by Newman, Hender, under licence from Canada. Known as the Newman-Velan, they are available as gate valves, ¼–2 in bore, working pressures up to 600 lbf/in² at 900°F, or as globe valves, ¼–3 in bore, for pressures up to 2500 lbf/in² at 1100°F.

Circle **No 547** on reply card

Power pack. A low-cost unit from Racal, the PU.56C, has a positive d.c. output in two ranges: 200–250 V and 250–300 V, at currents up to 250 mA. Input regulation is 0·1% for a 6% change in mains voltage; ripple is 8 mV r.m.s. Also provided are a stabilized supply of −150 V

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to within 0·5°C

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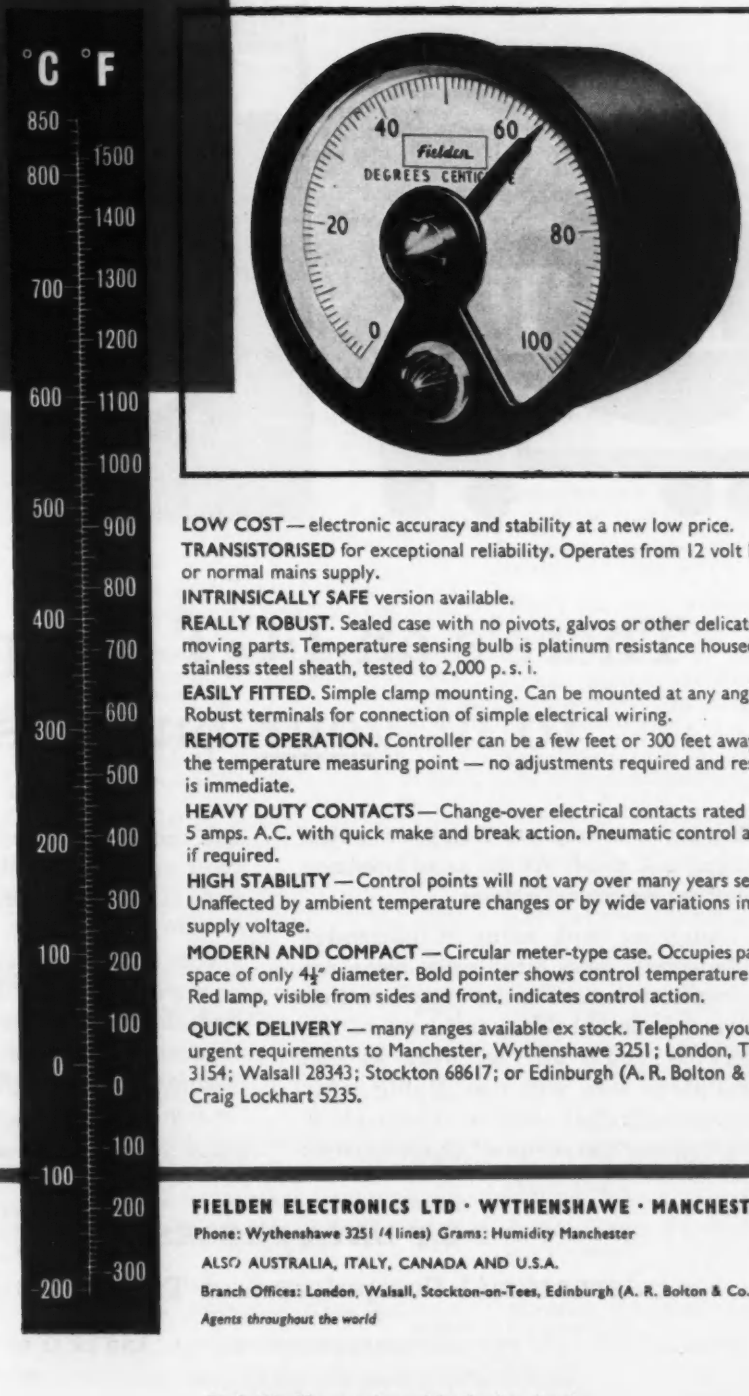

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REALLY ROBUST. Sealed case with no pivots, galvos or other delicate moving parts. Temperature sensing bulb is platinum resistance housed in stainless steel sheath, tested to 2,000 p. s. i.

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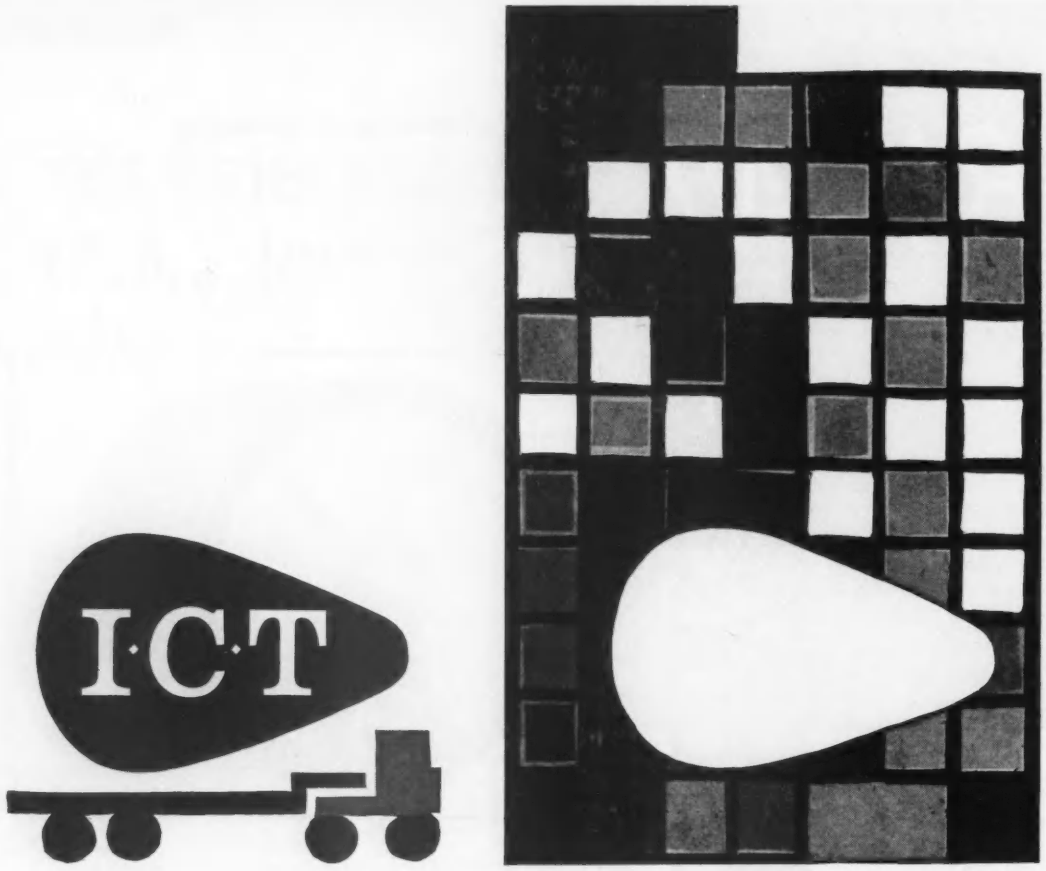

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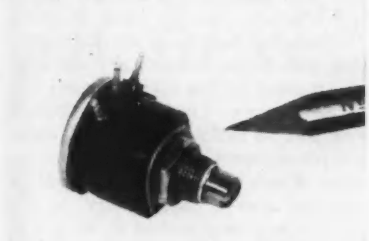
d.c. giving up to 15 mA, and a non-stabilized output of 4 or 6·3 V a.c. at 3 A, or 6·3 V a.c. at 2·5 A.

Circle **No 548** on reply card

Control valve. The Masoneilan 20,000-series valve is available with flanged connexions in sizes up to 10 in, as well as with screwed connexions up to 2 in as mentioned on p. 137 of our April issue. Made by Crosby Valve.

Circle **No 545** on reply card

Wirewound control. General Controls' wirewound control is 0·916 in diameter by 0·66 in deep, and will dissipate 3 W. A special silicone-glass laminated former



is used, and the unit may be supplied fully sealed and tropicalized: maximum resistance value is 50 kΩ.

Circle **No 554** on reply card

Miniature switch. A panel-mounting toggle switch by M.E.C. has a body ¼ in diameter by ½ in deep. Rating is given as 1 A at 50 V d.c.

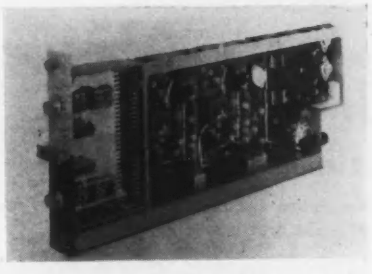
Circle **No 560** on reply card

Counter tube. The Elesta decade counter selector tube EZ.10B is available from Britec. It is a miniature gas-filled tube, with a maximum counting speed of 1 Mc/s. Circle **No 549** on reply card

Differential refractometer. An instrument by H.H. Controls (U.S.A.) provides a polarized electrical output indicative of the difference in refractive index of two fluids contained in separate cavities. A transistor amplifier provides a linear output up to ±1·5 V from null. Sensitivity is quoted as better than ±0·00001 of refractive index.

Circle **No 550** on reply card

D.C. amplifier. The Redcar model 500, available from Packard Bell (U.S.A.), contains two single-ended amplifiers in one package using a common power



supply. Gains are adjustable from 10 to 10,000, and bandwidth from 10 c/s to 100 kc/s. Input impedance is greater than 1000 MΩ, and output may be up to ±10 V at 100 mA.

Circle **No 553** on reply card

Logic elements. Available from Panellit is a fully encapsulated version of the Minilog solid-state logic system for sequencing and control applications. Two types of elements are available: one provides an 'inverted and' function, driving up to five inputs; the other incorporates an emitter-follower and can drive up to 25 inputs. Size of either unit is 2 × 0·85 × 0·63 in.

Circle **No 544** on reply card

PUBLICATIONS RECEIVED

Mathematics of engineering systems (linear and non-linear) *by* **Derek F. Lawden.** *Methuen & Co. Ltd. 1961. 404 pp. 12s. 6d.* ★575

Modern computing methods. *D.S.I.R. 1961. 170 pp. £1 1s.* ★576

Hydrodynamic seal for rotating shafts *by* **E. F. Boon and S. E. Tal.** *U.K.A.E.A. Risley. 1961. 30 pp.* ★577

Radioisotope data *by* **R. A. Allen, D. B. Smith and J. E. Hiscott.** *Wantage Research Laboratory, U.K.A.E.A. 1961. 200 pp. 8s.* ★578

Space communications (Ultra Anniversary Lecture) *by* **John E. Taber.** *Ultra Electric (Holdings) Ltd. 1960. 20 pp.* ★579

An introduction to electronic data processing for business *by* **Leonard W. Hein.** *Van Nostrand Ltd. 1961. 320 pp. £2 16s.* ★580

A direct reading flame photometer of high sensitivity *by* **A. Hinde.** *U.K.A.E.A. 1961. 28 pp.* ★581

Design fundamentals of analog computer components *by* **R. M. Howe.** *Van Nostrand Ltd. 1961. 268 pp. £2 16s. 6d.* ★582

Improvements to the cathode ray polarograph *by* **J. E. Seaborn.** *A.E.R.E. Harwell. 1961. 6 pp. 1s. 9d.* ★583

The business of management *by* **Roger Falk.** *Penguin Books Ltd. 1961. 251 pp. 3s. 6d.* ★584

Control of nuclear reactors and power plants *by* **M. A. Schultz.** *McGraw Hill Publishing Co. Ltd. 1961. 462 pp. £4 17s.* ★585

Recorders. Kent's Mark 3 Multelec instrument is described in their leaflet No. 295. ★587

Isolated power supplies by Elcor (U.S.A.) are featured in catalogue 3-361-10M ★588

Open-channel flow-measuring instruments are the subject of specification sheet SS013 from George Kent. ★589

Equipment wire of all types is listed in a comprehensive illustrated catalogue (H12, ed.2) from S.T.C. ★590

Mesa h.f. transistors by Siemens are described in a leaflet from R. H. Cole. ★591

Computer output printer. Rank's Xeronic is the subject of a 12-page technical booklet. ★592

Screw feeder for powders, flakes, and pellets, the Vibra, is shown in a leaflet from Simon Handling Engineers. ★593

Tangential-flow fans for technical applications are described in a leaflet from Solartron. ★594

Pre-formed wiring by Rist's is illustrated in leaflet G61126. ★595

Asbestos for use in the electrical industry is described in an illustrated 32-page booklet from Turner Bros. ★596

Electrical test gear by Electro (U.S.A.) is listed in a leaflet from Livingstone Laboratories. ★597

Miniature bearings for many applications are listed in an anniversary catalogue from Miniature Bearings Ltd. ★598

Air-operated receiving instruments by Kent are specified in SS010. ★599

Precision a.c. servomotors by Elliott are the subject of leaflet W.21/1. ★600

'Simple oscilloscope measurements' is the title of a booklet from the Mullard Educational Service. ★601

Contacts. Standard-headed rivet-type contacts by Johnson, Matthey are the subject of a recent data sheet. ★602

Ring balance meters by Hagan are described in an illustrated booklet, HC 401. ★603

Nucleonic equipment by Dynatron and Ekco is the subject of a comprehensive 72-page catalogue. ★604

Silicone rubbers by Midland Silicones are listed in a technical data sheet K32, ed.2. ★605

Multi-channel recording system. Data sheets 010860/1 to 010860/33 cover Thermionic Product's transistor model series III. ★606

Radiation switch. The Simcar radiation switch is described in a leaflet from A. M. Lock. ★607

Voltage regulator. The Regohm, made by Electric Regulator Corp. (U.S.A.), is the subject of bulletin 505.00 from B.K.B. Electric Motors. ★608

Synchros. Ellsyn stub synchros are described in publication W26 from Elliott Bros. ★609

Cable-fault locator. Details of a transistor instrument by Addison Electric are given in a recent leaflet. ★610

★ Circle the relevant number on the reply card facing page 162 for further information

Book Reviews

Automation

Automation and Skill *by* **E. R. F. W. Crossman.** *D.S.I.R. 1960. 60 pp. 3s. 6d.*

This booklet of about sixty pages is the ninth of a series on industrial problems sponsored by the Department of Scientific and Industrial Research. The purpose of the booklet is to discuss the new issues raised by automation techniques so far as they reflect the changing pattern of requirements for human skill. The report is based on visits to widely different factories, including plants manufacturing motor-cars, valves, cigarettes, textiles, paint, biscuits, margarine and heavy chemicals, in all of which there is some degree of automation. Automation is considered to be divided into three types; continuous-flow production, use of programmed machines, and centralized remote control. The most impressive findings relate to plants in continuous-flow production. In these there is a tendency to require control and communication skills and to produce a new type of preventive-maintenance routine worker. The chief requirement for the former is *decision*, i.e. selection of the best control action for each combination of circumstances that arises.

There appears to be a considerable variation in control skill: less effective operators tend to work by rule-of-thumb and better ones by intuitive appreciation of the whole state of a process, possibly by making a mental working model. This is a rather fascinating conclusion. Designers of highly automated systems have a similar choice between basing systems on 'automated rule-of-thumb technique' or going the whole hog to create a genuine electronic process-model to which all automated decisions can be referred. In spite of a lot of talk about self-optimizing computers the present evidence, according to my experience, is that most practical automation systems are 'automated rule-of-thumb'. It might be worth while for some of our electronic companies studying the application of computers to processes to investigate intensively how good human operators come to their control decisions, since it may be that the human psyche has remarkable resources for making 'process model pictures'. According to the report under review, process operators can sometimes achieve better results than a trained engineer thinking logically about control problems: it appears that there is no rational approach to very complicated events and that some degree of intuition is essential.

Repetitive manual jobs tend to be substantially abolished in automated production, but they reappear under the cloak of planned maintenance. This emphasizes the difference between the type of work done by preventive-maintenance crews and shift-maintenance staffs. The latter must be able to deal rapidly with unforeseen break-downs, and may need diagnostic skills of a high order.

Whilst this short report only sketches the outlines of the problems, it appears to be a very valuable contribution. It could be studied to advantage by both automation users and equipment suppliers.

D. B. FOSTER

Rockets

Kinetics, equilibria, and performance of high temperature systems. *Edited by* **Gilbert S. Bahn** *and* **Edward E. Zukoski.** *Butterworths Scientific Publications Ltd. 1960. 255 pp. £4.*

This book gives the proceedings of the first conference on the subject of the title, which was held by the Combustion Institute in Los Angeles from the 2nd–5th November, 1959. The conference was sponsored by the Marquardt Corporation and by Rocketdyne, and supported by the Air Research and Development Command. A small amount of confidential work presented at the conference is not included in the book.

From its origins it would appear that the subject of the book is highly specialized and the high-temperature systems considered are without exception rocket motors. The papers in fact cover exhaustively, and with a great deal of repetition, the problem of calculating the performance of a rocket engine. The majority of the papers are concerned with calculations of the thermodynamic performance.

For control purposes the most interesting part of the book will be that on kinetics and on instrumentation. Unfortunately this part of the book is slender and not of obvious use for control. There are, for example, papers on a combustion model with droplet break-up, and studies of chemical non-equilibrium in hypersonic flow nozzles. The emphasis here is strongly upon engine performance. The one paper on instrumentation is entitled 'Criteria for design and development of automatic, self-linearizing, self-editing, electronically calibrated transducers'. The hopes aroused by this comprehensive title are disappointed in the performance. The paper considers at arm's length a number of possible techniques, and ends with a recommendation for a literature study.

To sum up, the book is of only marginal interest from the point of view of automatic control. Apart from its own specialized field of rockets it may be consulted by those concerned with equilibrium in high-temperature chemical systems. It presents a great deal of experience in the calculation of chemical equilibria in these systems. It also presents considerable experience with computer techniques for solving sets of non-linear equations or for finding the minimum of a function.

The production of the book is good, though the level of technical writing is often low. An example, not by any means unfair, is the following:

> An extension of event counting concepts leads to regional boundary transducers. Essentially, the boundary for a region may be detected by an event counter. Such a sensor may be considered as a type of narrow band filter. The actual physical parameter indicated must be recognised in two senses. First, a boundary crossing must be sensed. . . .

Here and in many similar places a vigorous use of the editors' pencil would have improved the book.

H. H. ROSENBROCK

Russian

Translation from Russian for Scientists *by* **C. R. Buxton** *and* **H. Sheldon Jackson.** *Blackie & Son Ltd. 1960. 299 pp. £1 10s.*

Soviet technical literature is both extensive and important, and though some of it is translated, most is available only in the original. To read Russian technical papers without much hard labour needs a thorough mastery of the language, which few engineers have the time or the opportunity to acquire. Even a more superficial reading knowledge of Russian however, is very useful and this book is specially designed to enable the student to acquire this easier accomplishment.

The volume starts with a section on grammar. This provides an excellent introduction to the Russian alphabet, the first obstacle in the way of the English student. The grammar is clearly and compactly presented and backed by illustrative translation exercises, but for the beginner the section may well prove difficult; more and simpler exercises would have been welcome. The book is completed by a good selection of Russian texts with a short vocabulary. These are designed for the physicist and chemist, and the control engineers will not find their special interests catered for.

In learning a language there is no substitute for a teacher. As a textbook for use under guidance this work will be very useful, but a student who wishes to learn Russian on his own with the aid of this volume alone will find it a very formidable task.

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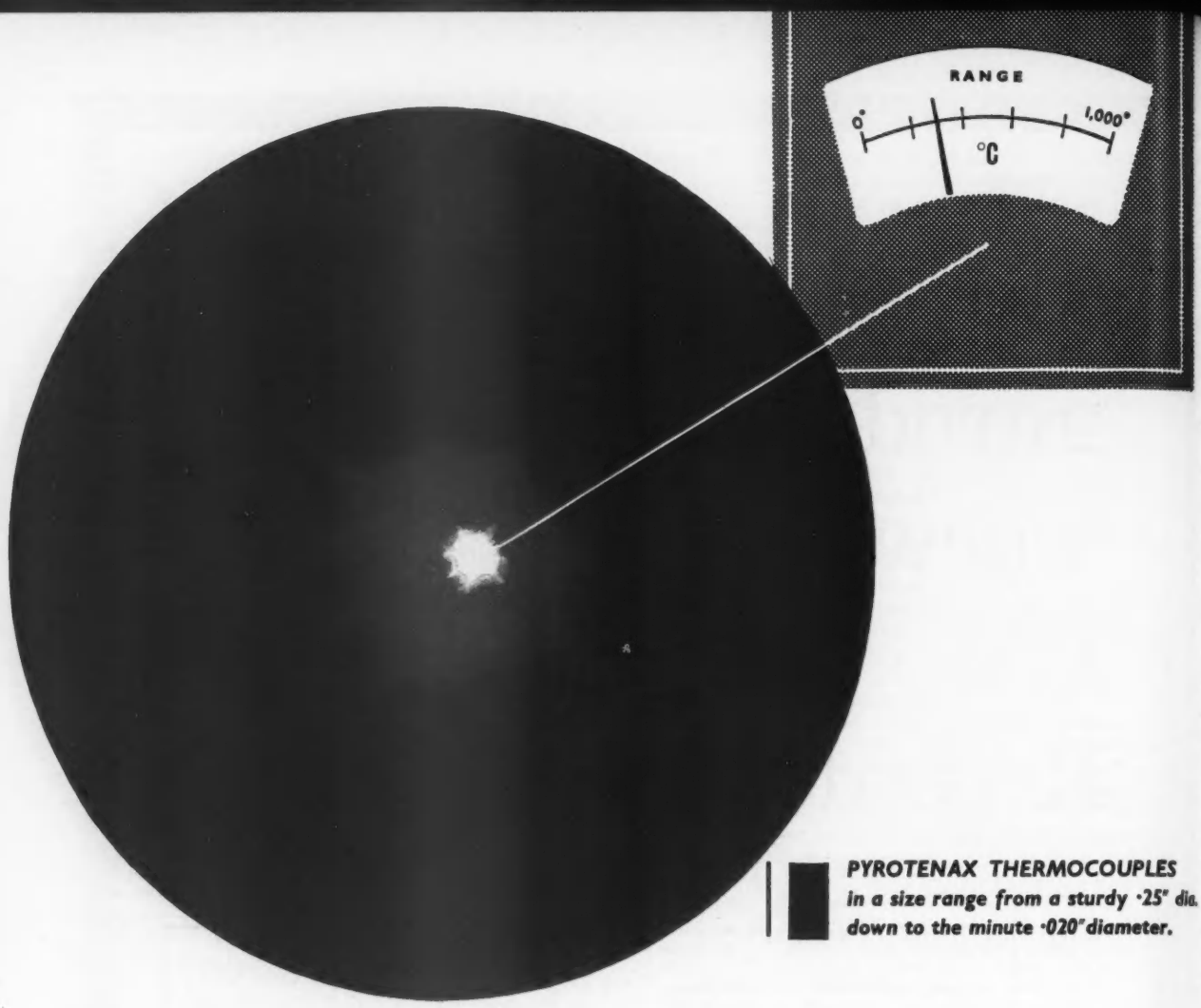

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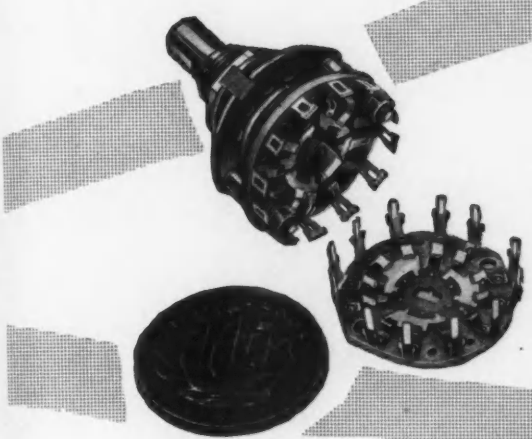

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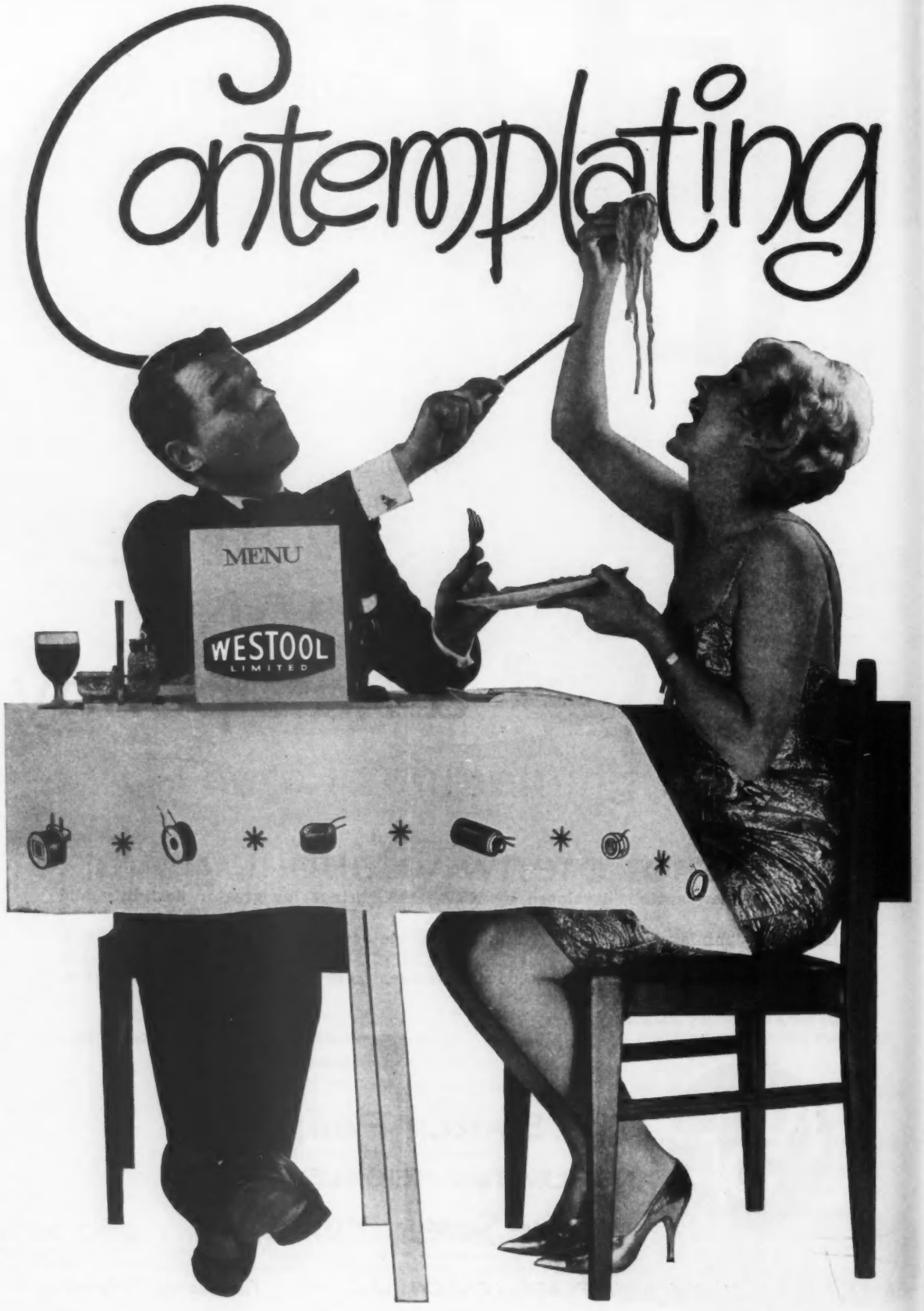
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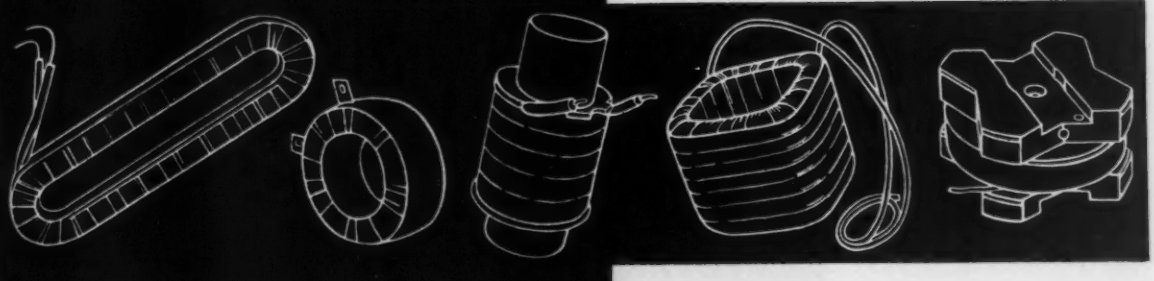

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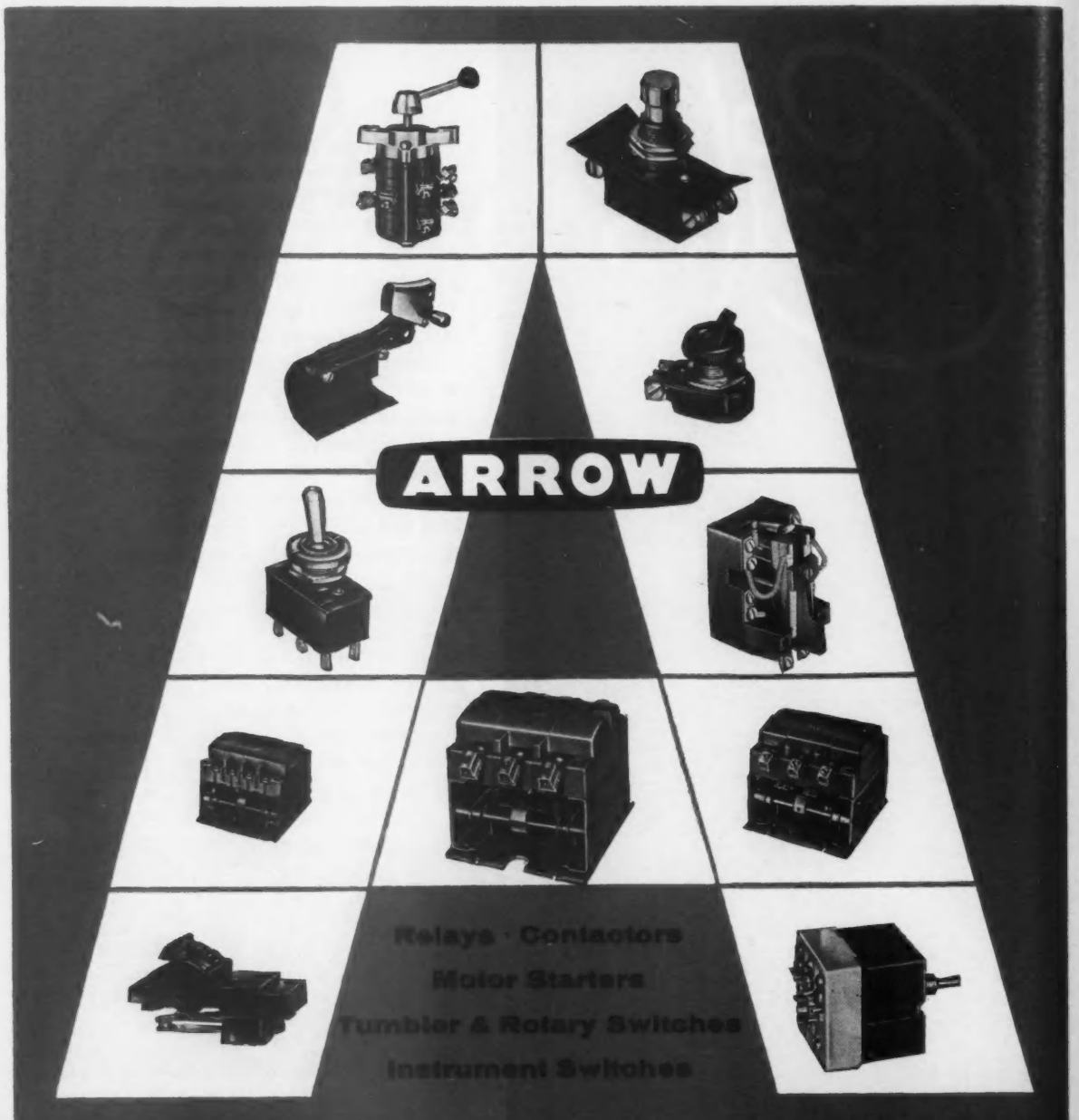

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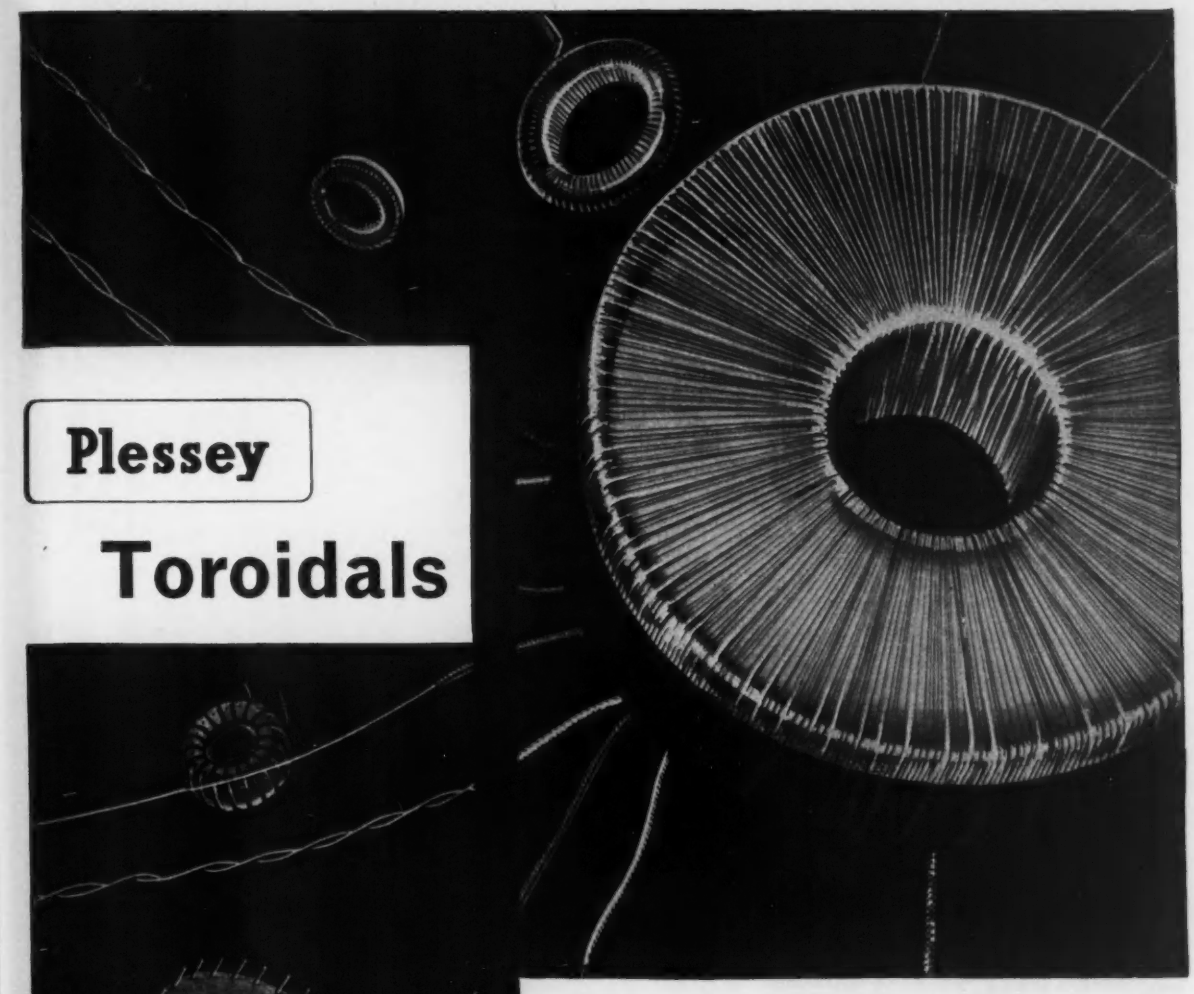
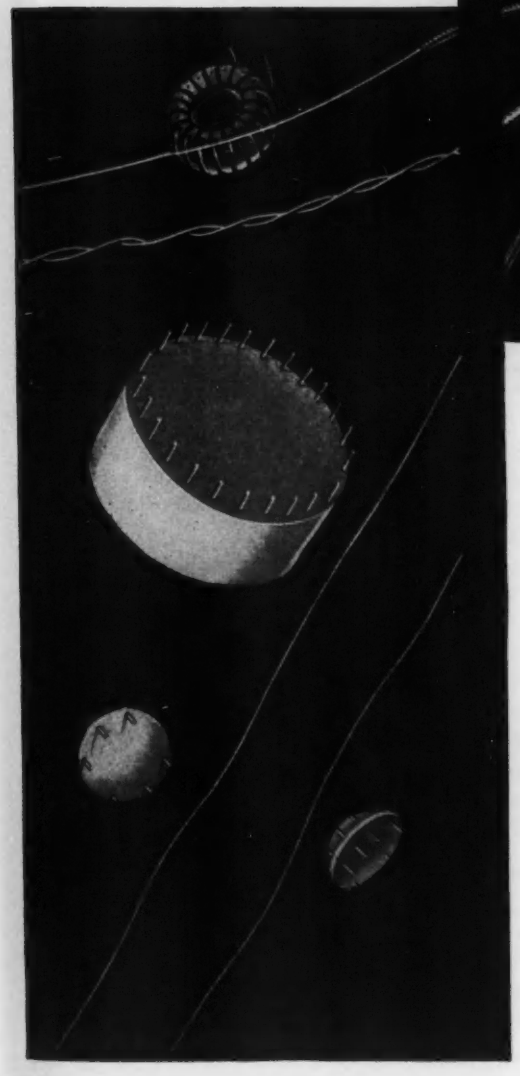


Plessey Toroidals



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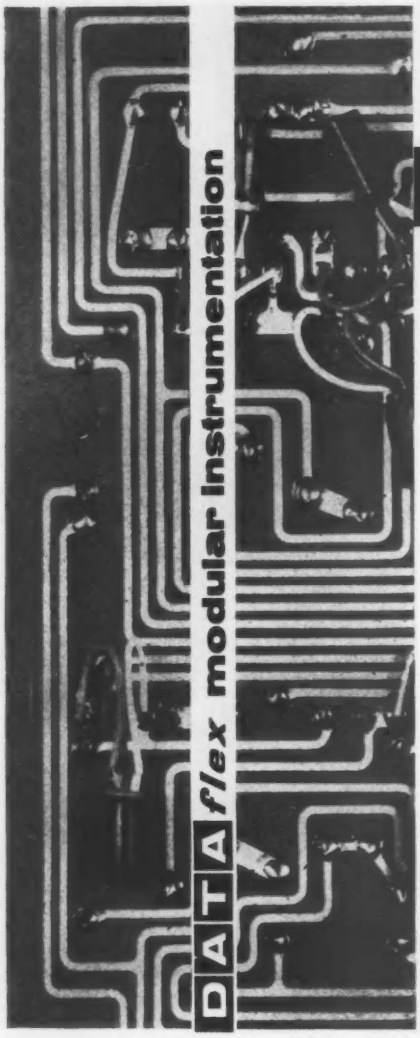

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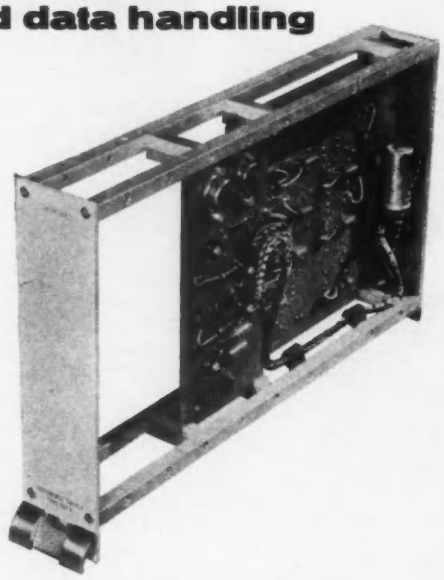

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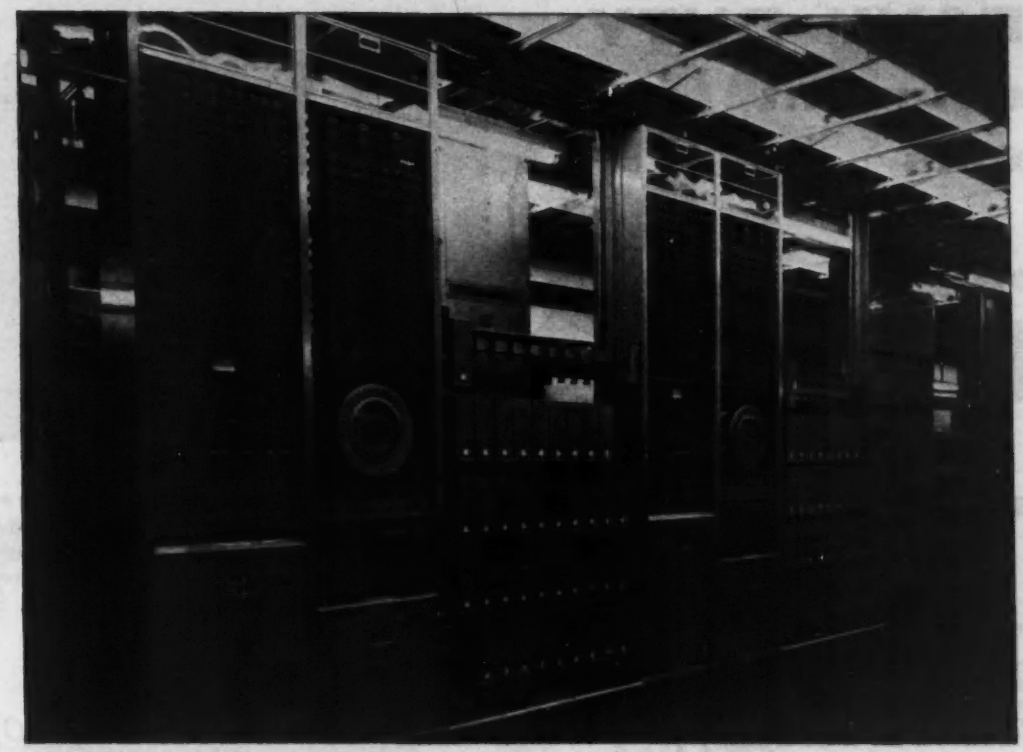
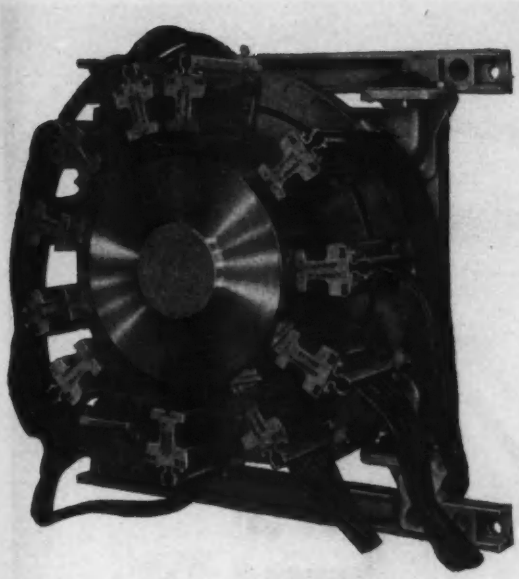
ER. 21 *(FORMERLY ERICSSON INSTRUMENT DIVISION)*



SPERRY answers the GPO's need



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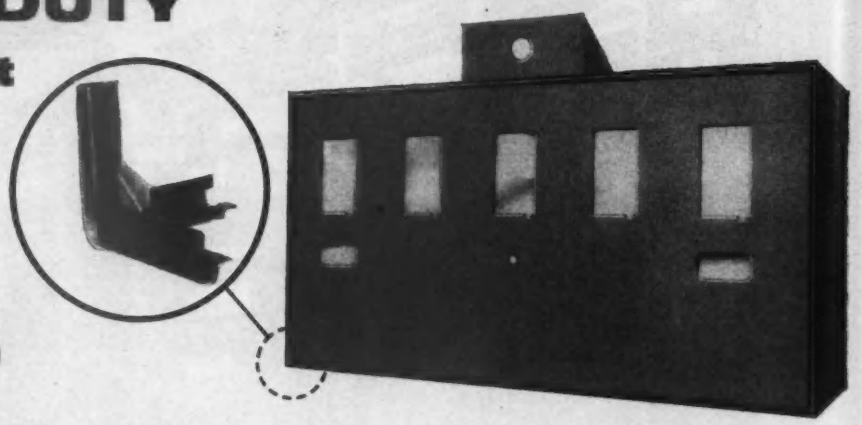
Instrument Racks
from
LUNDS
of Wandsworth



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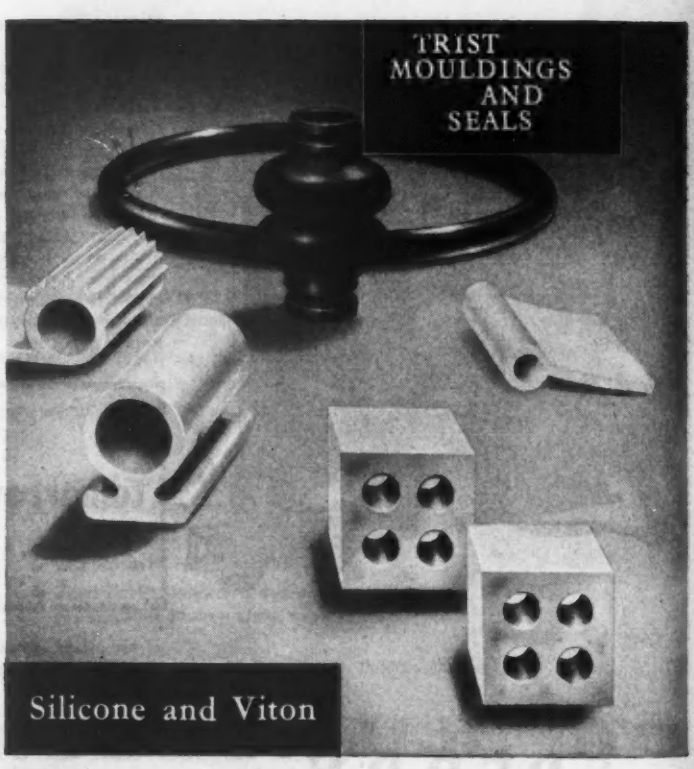

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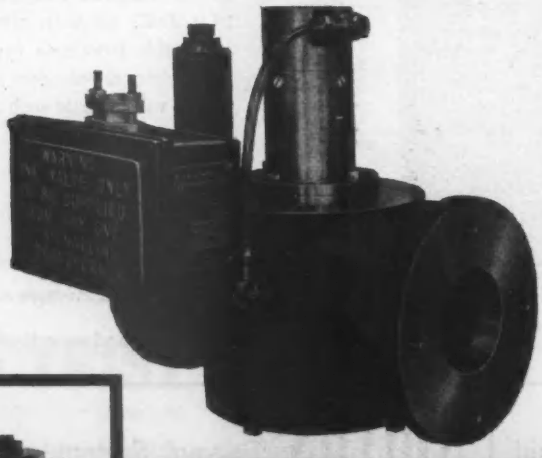

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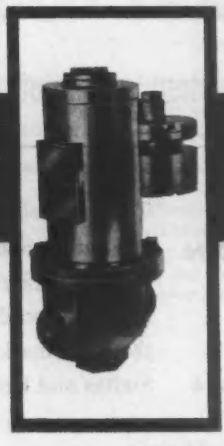

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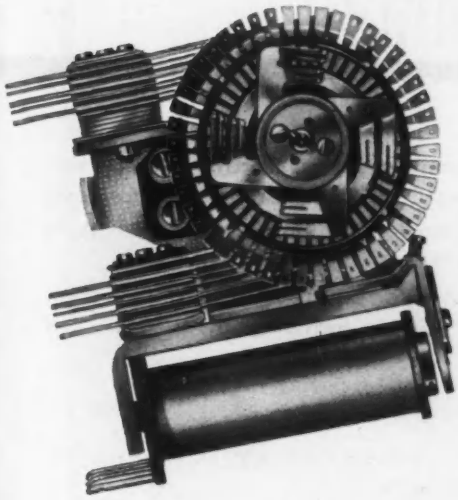
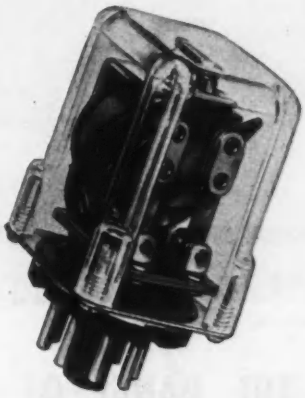


THERMAL TIME DELAY RELAY ▶

◀ 3 IN 1 RELAY



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2. ROTARY SWITCH Ratchet driven with four banks of twelve points each with bifurcated spring wipers. Transparent dust-cap fitted as standard.
3. STANDARD RELAY Knife-edge armature pivot operating 2 c/o and 1 n/o contacts.
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Coil Voltages: 12, 24, 46, 60 and 110 volts D.C.
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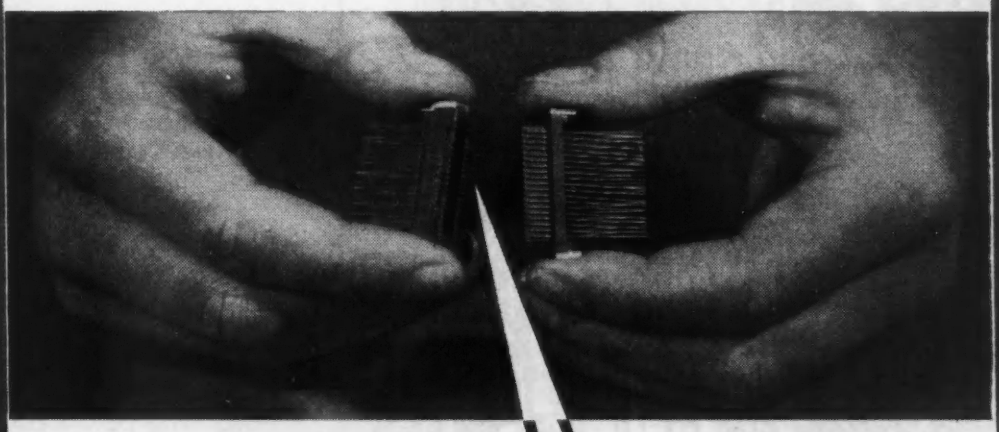

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26	·98 sq. ins.	1951
57	·306 „ „	1955
96	·146 „ „	1960
74	·072 „ „	1961

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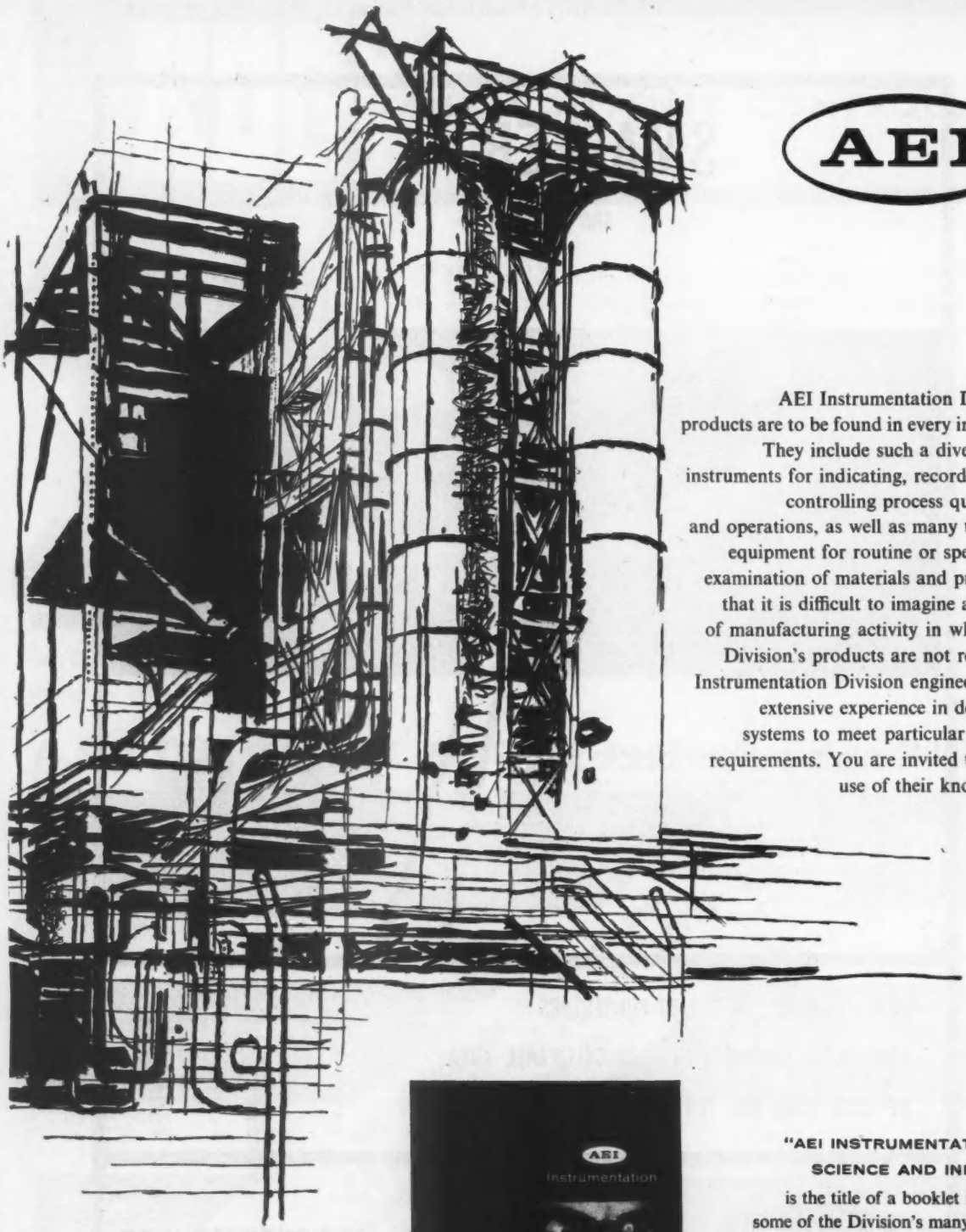

AEI

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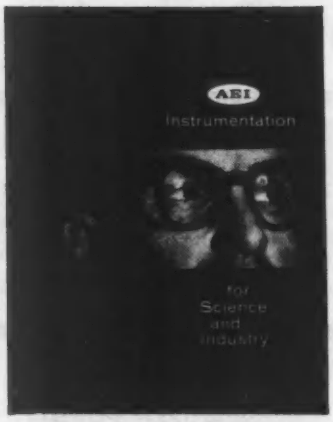

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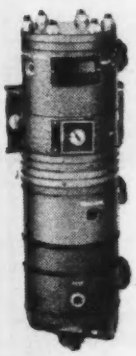
Instrumentation serves industry



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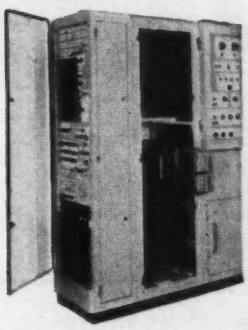

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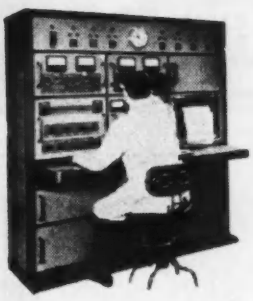
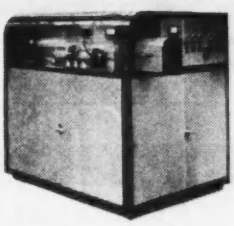
ranges from units for simple monitoring/logging of process values to systems with computation facilities for use in plant optimisation.





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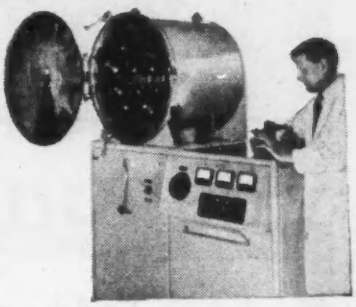

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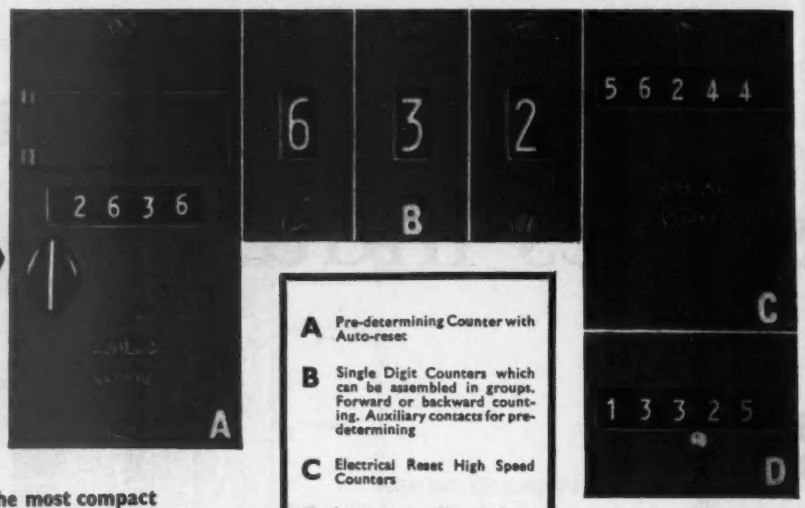
small

impulse

counters



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B Single Digit Counters which can be assembled in groups. Forward or backward counting. Auxiliary contacts for pre-determining

C Electrical Reset High Speed Counters

D Instantaneous Manual Reset High Speed Counters (10 or 25 impulses per second)

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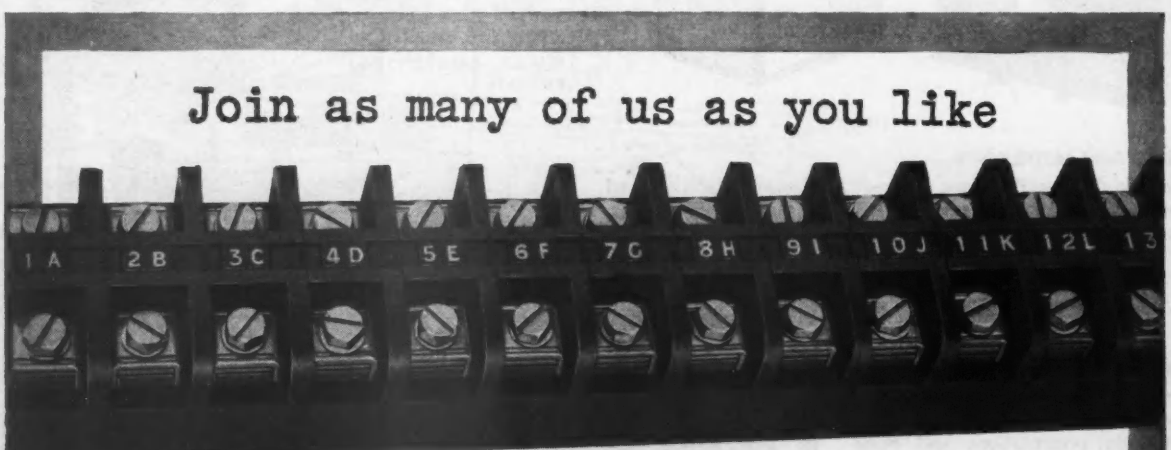
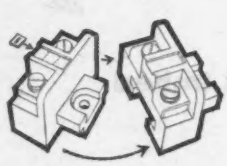


MTE MULTI-LOCK TERMINAL BLOCKS



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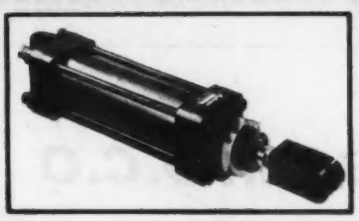
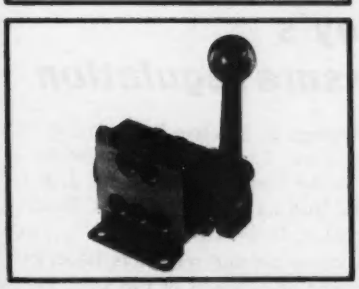
CONTROL in Industry





Martonair offer three ranges of cylinders—Minor, Standard and Heavy Duty—from ¼" to 12" diameter, and a range of over 400 control valves.

can be allied to power.

Martonair cylinders offer thrusts from a few pounds to a few tons—the power required to lock a safety catch or open a furnace door—the power to close a valve or operate a brake. Control valves enable the thrust, speed and position of cylinders to be varied, and Martonair equipment is in action every day in hundreds of industries in thousands of different ways, from a simple one cylinder-one valve combination to fully automatic circuits where electrical, electronic and hydraulic systems are combined with pneumatics.

Martonair pneumatics means control with Power

Martonair
The FIRST name in applied pneumatics

MARTONAIR LIMITED

Parkshot, Richmond, Surrey, England. Tel: RIC 2201 (6 lines)

and in Australia, Belgium, Canada, Denmark, Finland, France, Germany, Holland, Iceland, Italy, New Zealand, Norway, South Africa, Spain, Sweden, Switzerland, U.S.A.

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Electrically Operated
COUNTER
AT NEW LOW COST

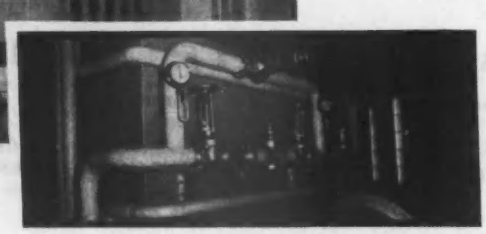
* Rated speed-up to 1000 Counts per minute
* Designed for panel or base mounting
* Centre reset by knob
* Connection by flying leads
* Maximum voltage 110 D.C.—250 A.C.

MODEL 442

English Numbering Machines Limited
Dept. 2K · QUEENSWAY · ENFIELD · MIDDLESEX
Telephone: HOWard 2611 (5 lines) Telegrams: Numgravco, Enfield

Full technical information on request

LEADING MANUFACTURERS OF COUNTING AND NUMBERING DEVICES



BARCLAYS BANK D.C.O
banks on Bailey's for steam pressure regulation

The entire pressure regulation system at Barclays Bank D.C.O., Goodenough House, Old Broad Street, London, was supplied by Sir W. H. Bailey & Co. Ltd. for the Consulting Engineers, J. E. Greatorex and Partners, and the Heating Engineers, Sulzer Bros. (London) Ltd. The architects were Ley, Colbeck, and Partners.

While specialising in the manufacture of pressure regulators, Bailey's are in a position to supply complete installations of this kind, incorporating isolating valves, strainers, relief valves, gauges and ancillary equipment. For medium and low pressure control installations in steam, water, oil, air and gases, you can bank on Bailey's.

Bailey's REGD.

SIR W. H. BAILEY & COMPANY LIMITED

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Albion Works, Patricroft, Manchester. Tel: Eccles 3487 (4 lines)
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Pressure Regulators · Sluice Valves · Test Pumps · Turnstiles

TEA G4A

BACKLASH ELIMINATED
PRECISE RESETABILITY
LAW ACCURACY ± 1·0% (ABSOLUTE)
or 0·25% IF REQUIRED

This ¾" diameter Helical of high quality yet inexpensive has been designed for manual operation and is available in two versions

1. **For standard wiring**
2. **For PRINTED CIRCUIT application using the accepted 0·1" grid**

HELICALS BY RELIANCE

10-TURN MINIATURE

TYPE HEL 07 – 10

SPECIFICATION

Resistance Range	**100-30,000 ohms**
Resistance Tolerance	**± 5%**
Law Accuracy (ABSOLUTE)	**± 1·0% or better to within 0·25% if required.**

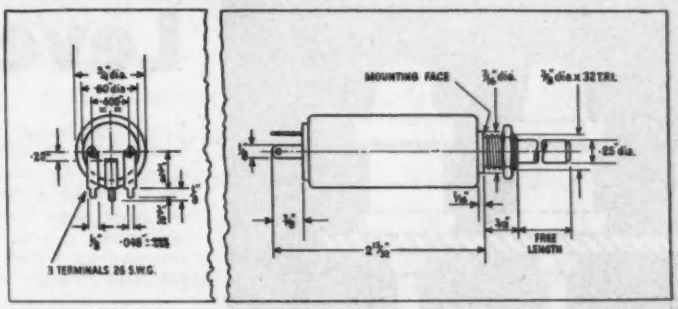
Independent Law Accuracy to closer limits.
Rotation—effective angle 3600° + 10° – 0°
Dials available if required.

Send for Data Sheets 11 and 12 which give full technical details and dimensions.

For SERVO application an entirely new Low Inertia multi-turn Synchro size unit is available

See below ★

DIMENSION DRAWINGS OF PRINTED CIRCUIT & STANDARD VERSIONS HEL 07-PC10 & HEL 07-10



★ FOR RESEARCH AND DEVELOPMENT ENGINEERS

concerned with servo systems, function generation and environmental simulation, Reliance by means of an entirely new technique (covered by world-wide patents) have developed and offer a multi-turn Potentiometer embodying in a single unit the following outstanding advantages

Size 11 Synchro Mounting
Low Torque < 6 gm. cm.
Low inertia < 0·01 gm. cm²
High Resolution
Multi-tapping Facilities
Multi Ganging

RELIANCE

RELIANCE MANUFACTURING COMPANY (SOUTHWARK) LIMITED

Sutherland Road, Higham Hill, Walthamstow, London, E.17. ***Tel: Larkswood 1118/9***

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RESIN CASTING and ENCAPSULATION

We offer complete DESIGN & DEVELOPMENT SERVICE

RESIN CASTING
achieves:

- **Robustness**
- **Protection:** Temp/Humidity
- **Miniaturisation**
- **Adaptability** Interchangeability
- **Weight:** Min. Increase
- **Security to:** Component/Circuit design
- **Standardisation**
- **Easier:** Assembly Servicing

RESIN MOULDINGS LTD
Manor Park Works, Manor Park Road,
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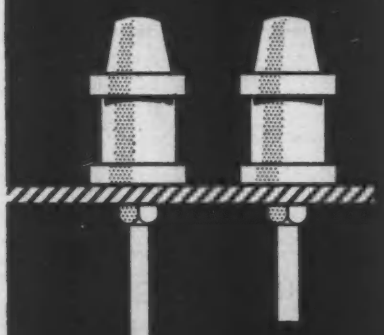
An Associated Company
WILLESDEN TRANSFORMER COMPANY LTD.
ELGAR 5445

LECTRALEVEL



Floatless Liquid Level Control

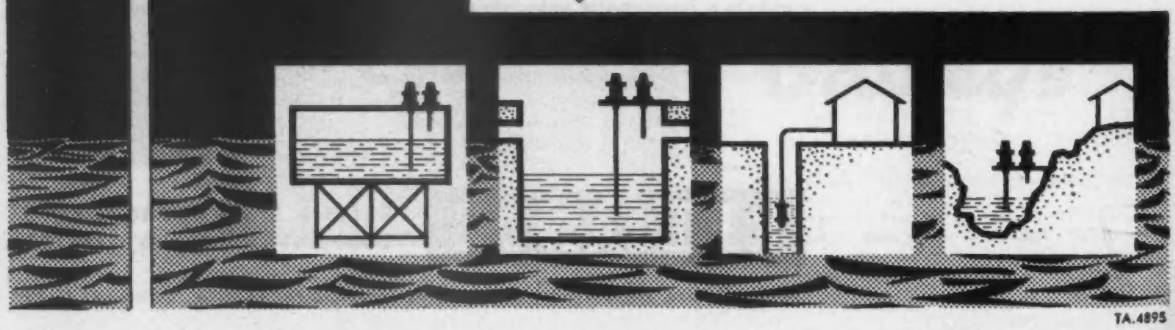
Lectralevel is a system for controlling automatically the filling or emptying of tanks. Lectralevel employs a simple, reliable electro-magnetic circuit based on the liquid conducting a very small current. A variety of electrodes and holders is available to suit most liquids and conditions.

Controls of this type have been in operation for over 20 years and require no maintenance.

Pump motors, valves, alarms, etc., can all be successfully controlled with Lectralevel.

Write for new fully illustrated booklet No. 94/C which tells how to apply Lectralevel in your plant.

LONDEX *Anerley Works, London, S.E.20.* *Telephone: SYDenham 3111*



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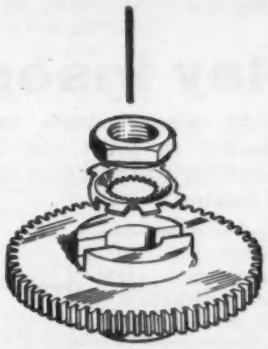
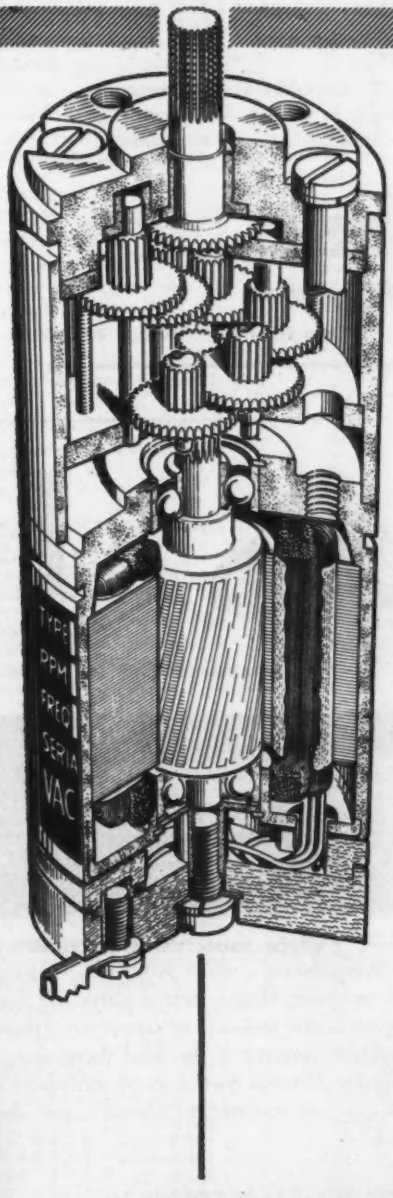


Vactric Control Equipment Limited,

and

Vactric Precision Tools Limited



wish to announce...

. . . that they have been acquired by the News of the World Organization Limited.

With such powerful backing, the future of these two Companies is assured. Not only will Vactric Control Equipment Limited continue to produce their present range of Precision Electrical Servo Components but the new backing will facilitate further developments. They will be pleased to consider fresh projects which are suited to their facilities.

Qualified Engineers, with experience in the field of Electrical Servo Components, who would like to join the Company at the commencement of this phase are asked to submit details of their past experience and training, to:—

VACTRIC CONTROL EQUIPMENT LIMITED,
Brunel Road,
ACTON, LONDON, W.3.

Both Companies invite enquiries relating to the activities for which they are well-known.

Vactric Control Equipment Limited
Vactric Precision Tools Limited

207 Sloane Street, London, S.W.1. Telephone: BELgravia 7000

NRP 5227

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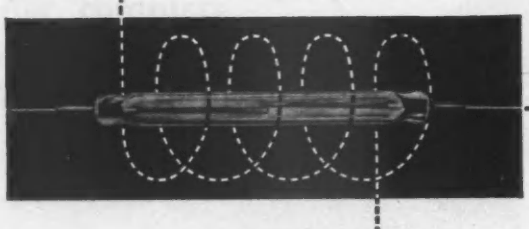
XS2 Dry Reed Relay Insert

A gold-plated relay contact hermetically sealed in inert gas for absolute reliability, high speed and low contact bounce.



Maximum current	250 mA
Maximum resistive load	15 W
Maximum closed resistance	50 mΩ
Minimum open resistance	5x10¹¹Ω

Nominal operate ampere turns	120 AT
Nominal release ampere turns	60 AT
Operate time less than	2 mS
Bounce time less than	0.5 mS
Release time less than	0.5 mS

Our Technical Service Department is ready to provide further details of characteristics or application.

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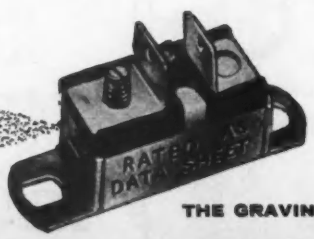
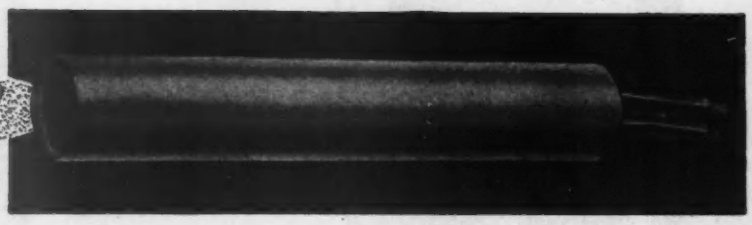
Pin-point Automatic Accuracy



THE GRAVINETTE

Write for Catalogue G. 100 Temperature Control Switches



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Type TCS 3151, normally open, range—70°C to 100°C,
Type TCS 3250, normally closed, range 40°C to 250°C,
Type TCS 3251, normally open, range 40°C to 250°C.

Normal rating 1 amp. on 250v A.C., and 2 amps on 28v D.C.

CARTRIDGE TYPE SERIES 1000, TENSION OPERATED

These precision temperature control switches are designed primarily for use in heater blocks, heated plates and similar applications where excessive moisture or vapour is not present. Possessing the desirable features of the ideal thermostat, the Graviner Temperature Control Switch is of convenient size and shape, adjustable and resistant to vibration and shock, and easy to install.

Current Rating 5 amps 250v. A.C. for standard types.

T TEMPERATURE
C CONTROL
S SWITCHES

For further details of our complete range write or telephone

GRAVINER, 10 CHURCH ST., STAINES, MIDDLESEX

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Specialists in Airborne and Industrial Fire and Explosion Protection, Nuclear Development and Production Engineering

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Il est souvent difficile au client publicitaire d'indiquer dans un espace restreint tous les détails de ses produits. Dans le cas où vous désireriez de plus amples renseignements à ce sujet, veuillez pointer le numéro approprié sur la carte ci-contre et envoyer cette dernière à CONTROL.

AUSKUNFTSDIENST FÜR LESER

Es ist oft schwierig für Inserenten alle technischen Einzelheiten über ihre Produkte in einem begrenzten Platz zu bringen. Sollten Sie noch weitere Auskünfte wünschen, streichen Sie einfach die bestimmten Nummern auf der nebenstehenden Karte an, und senden Sie sie an CONTROL.

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E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desideraste ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a CONTROL.

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Часто бывает трудно рекламирующим дать все технические подробности своей продукции в рекламе. Если Вам понадобятся добавочные сведения, то просто отметьте соответствующие номера на карточке на противоположной стороне и отправьте в CONTROL.

請告詢問服務

在廣告上以有限的地方來解釋一些專門技術及它們的功能，的確是有受限制的困難。若請求收集和進一些詳細的情報，就請將下頁的表格取一張下來，將閣下有疑問的項目，用筆勾一下即寄給子能工社處理可。

讀者サービス

廣告紙面の関係上製品の技術的細目は掲載しきれません。ので詳しくは貴社のカードの適当なナンバーに印をつけて原子力現社あてお送りしてくだされればお答へします。

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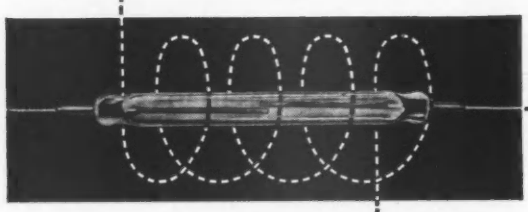
A gold-plated relay contact hermetically sealed in inert gas for absolute reliability, high speed and low contact bounce.



Maximum current	250 mA
Maximum resistive load	15 W
Maximum closed resistance	50 mΩ
Minimum open resistance	5x10¹¹Ω

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Nominal release ampere turns	60 AT
Operate time less than	2 mS
Bounce time less than	0.5 mS
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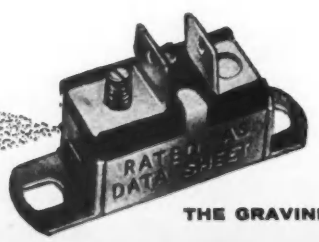
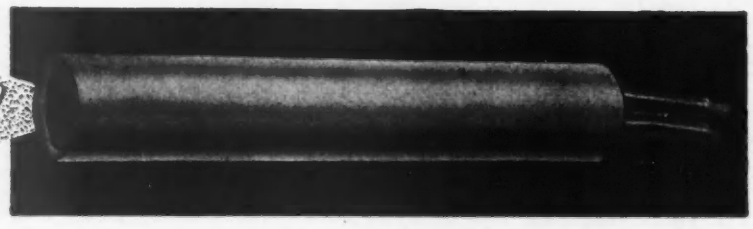
Pin-point Automatic Accuracy



THE GRAVINETTE

Write for Catalogue G. 100 Temperature Control Switches



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C CONTROL
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讀者サービス

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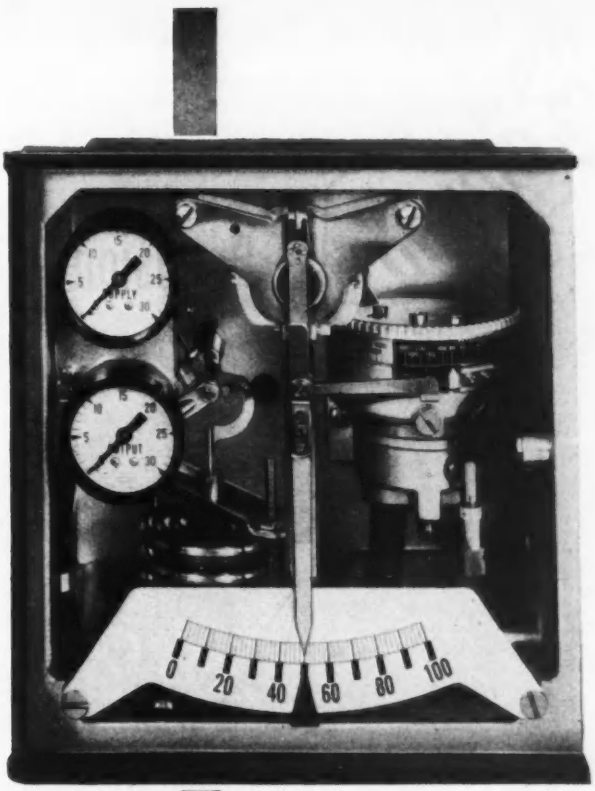
New advanced design indicating pneumatic controller



BRISTOL'S

SERIES 624

Highlight of this new indicating pneumatic controller is the new Bristol advanced design control unit.

It can be used with a wide range of measuring elements, and any of the standard Bristol precision measuring elements for pressure, temperature, and flow can be used with this instrument.

The control unit is made entirely of aluminium, stainless steel, Ni-Span C and neoprene. A Ni-Span C feedback bellows gives excellent ambient temperature stability.

The control unit has an efficient, compact design that is easily replaceable and can be calibrated either in the instrument or in the instrument shop.

SPECIFICATIONS

MODEL No: 624

CASE: Cast aluminium 8" x 8" x 5".

MEASUREMENTS:

Pressure – full vacuum to 10,000 psi.
Temperature – minus 100°F to +1000°F.
Flow and level – wide range with both mercury and dry type meter bodies.

CONTROL:

Proportional with 1 to 400% proportional band, direct or reverse action (Model 624B).
Proportional-plus-reset control unit. Proportional band adjustable 0-400%. Reset rate adjustable from less than 0.1 to more than 100 repeats per minute.
Proportional-plus-derivative control unit. Proportional band is adjustable 0-400%. Derivative time is from 0-10 minutes.

PILOT VALVE:

Non-bleed, high capacity. Low air consumption.

ELLIOTT

Full details from PROCESS CONTROL DIVISION

ELLIOTT BROTHERS (LONDON) LIMITED

Incorporating BRISTOLS INSTRUMENT COMPANY LIMITED

Century Works, Lewisham, London SE13 Telephone: TIDeway 1271

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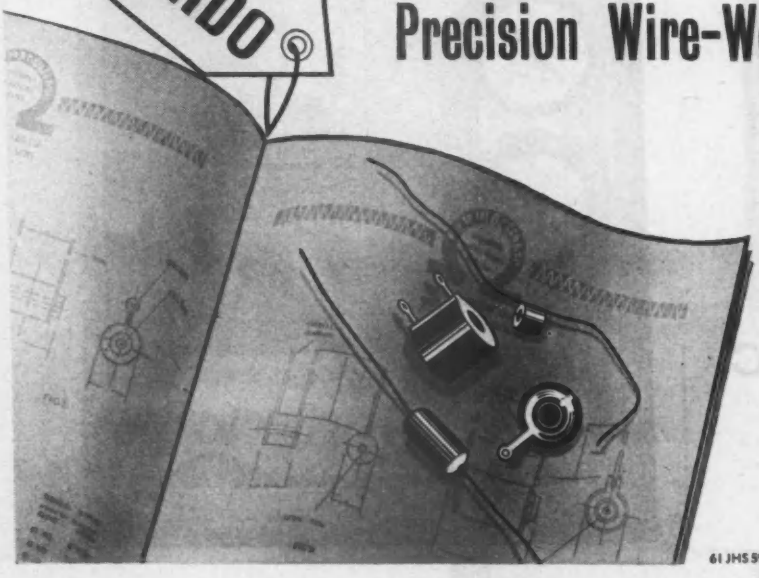

If you are a designer or engineer in computer circuitry, instrumentation or any other field of electronics you will find this McMurdohm Resistor technical catalogue invaluable. Send for your copy.

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61 JHS 5987

How does NBD sight radio stars?

Acknowledgements to Husband & Co., Consulting Engineers.

At Jodrell Bank, the world's largest steerable radio telescope, there are Newton Derby servo motors. They are an essential link in orientating the 2000-ton telescope with the extreme accuracy demanded by the radio astronomer. When radio stars are sighted at Jodrell Bank, NBD is there.

● Servo Motors ● Permanent Magnet Alternators ● Motor Generator Sets ● Automatic Voltage Regulators ● Transistor Convertors ● Rotary Transformers and Convertors ● High Frequency Alternators (400 to 3,000 c.p.s.)

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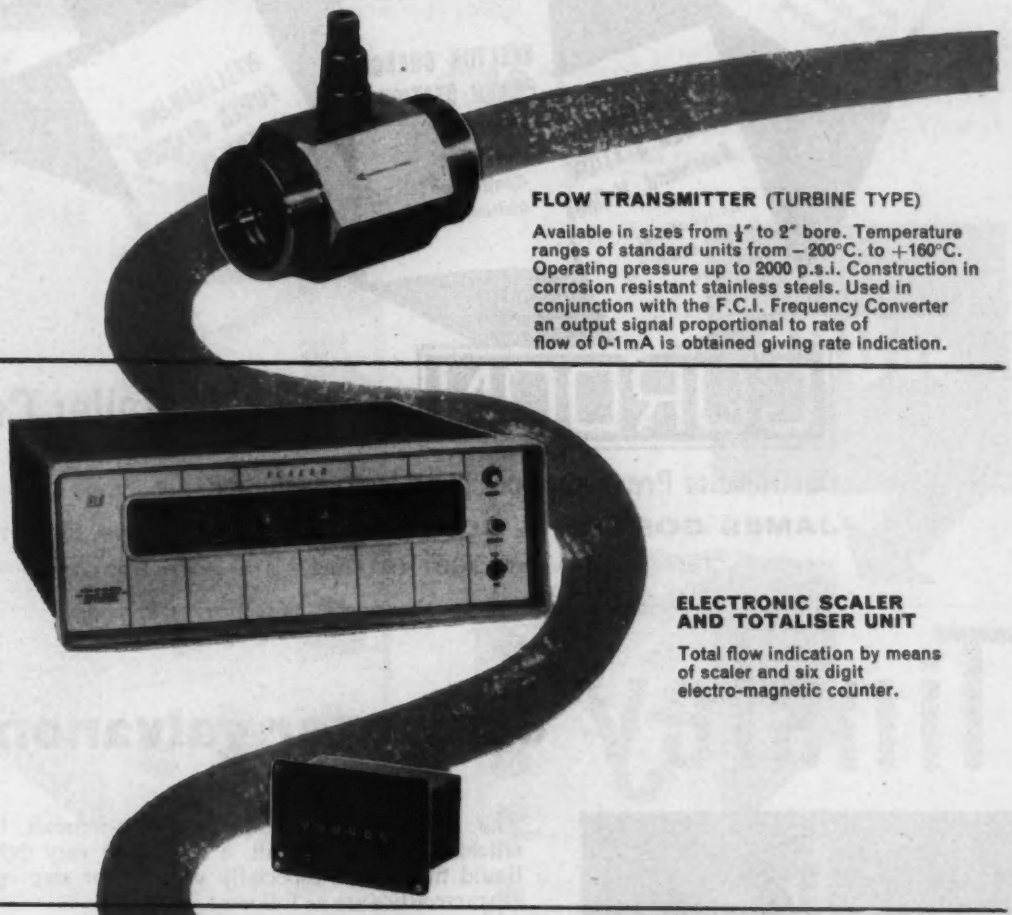
NEWTON BROS. (DERBY) LIMITED, ALFRETON ROAD, DERBY.
Telephone: Derby 47676 (4 lines). Grams: DYNAMO DERBY.
London Office: IMPERIAL BUILDINGS, 56 KINGSWAY, W.C.2.

accurate measurement of liquid flow

This new range of FIRTH CLEVELAND FLOWMETER EQUIPMENT sets high standards of accuracy in the measurement of liquid flow—both for rate and total quantity.

- Flow rates from 0.25 to 300 g.p.m.
- Longscale indication of rate of flow
- Total throughput shown in digital form on electronic or electromagnetic display units
- Turbine Type Transmitter is glandless; has only one moving part.



FLOW TRANSMITTER (TURBINE TYPE)

Available in sizes from ¼" to 2" bore. Temperature ranges of standard units from −200°C. to +160°C. Operating pressure up to 2000 p.s.i. Construction in corrosion resistant stainless steels. Used in conjunction with the F.C.I. Frequency Converter an output signal proportional to rate of flow of 0-1mA is obtained giving rate indication.

ELECTRONIC SCALER AND TOTALISER UNIT

Total flow indication by means of scaler and six digit electro-magnetic counter.

FLOW RATE INDICATOR

Suitable for flush or projection mounting. Available in dial sizes of 4", 6" and 8" which can be scaled in gallons, metres, percentage of flows etc.

We shall be pleased to send you information about any or all of these units.

FCI FLOWMETER EQUIPMENT

Firth Cleveland Instruments Limited, 7 Cleveland Row, London, S.W.1. WHitehall 3100.
Works and Head Office: Treforest, Pontypridd, Glamorgan **A MEMBER OF THE FIRTH CLEVELAND GROUP**

CRC 359

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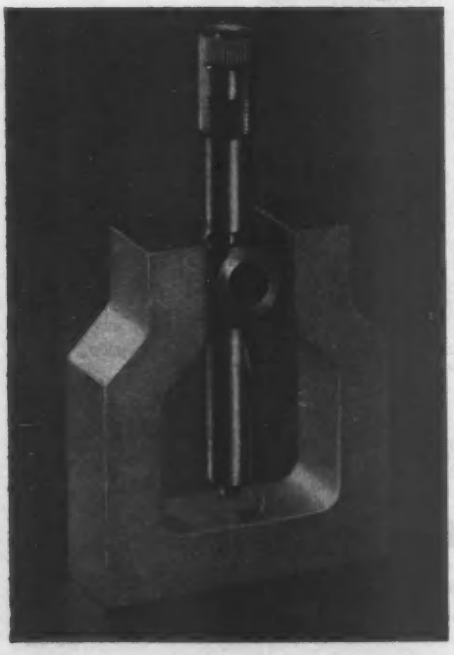
Tinsley computer galvanometer



The new Tinsley Computer Galvanometer has a highly efficient magnetic circuit, a small and very light coil and is liquid filled. It is especially suitable for step recording. The characteristics are as follows :—

Sensitivity: 3420 mm/μA at one meter scale distance
Damping resistance: 60000 ohms
Zero shift: less than 1 mm after 500 times overload
Balance factor: 30
Time constant: 140 seconds

The complete range of Tinsley Galvanometers covers all possible applications in experimental work. It includes: —

Sensitive d.c. Galvanometer with or without Amplifier

Ballistic	**Quick response**
Long periodic time	**Marine**
Liquid filled	**Computer**

Vibration Galvanometer with or without Amplifier

For details of galvanometers to meet your specific requirements, write to:—

H. Tinsley & Co. Ltd.

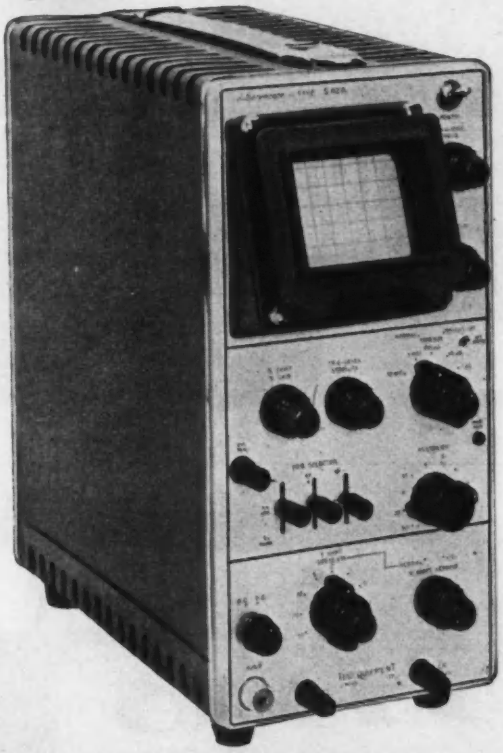
Werndee Hall, South Norwood, London, S.E.25

telephone: ADDIscombe 6046-8

9 Mc/s

The versatility of the Serviscope* range of portable and rack-mounted oscilloscopes has now been increased by the introduction of two new instruments...PA2, a Twin Channel Pre-amplifier, and S42A, a Wide-Band Serviscope. The Pre-amplifier, though designed primarily for the Double-beam Serviscope, D31, is quite suitable for any oscilloscope in the Serviscope range.

Used in conjunction, the two new instruments give exceptionally high performance—DC 100mV/cm at 9Mc/s, and 10mV/cm at 0.5Mc/s, AC 100μV/cm at 150Kc/s—at a total cost of less than £130.



S42A Wide-range High-performance Serviscope

The S42A carries the development of the Serviscope a stage further. Y amplifier bandwidth has been increased to 9Mc/s at the normal gain of 100mV per cm. whilst preserving all the normal features of the S42, including the 10 x gain facility at limited bandwidth. This feature should make the oscilloscope ideally suited to work at the highest video frequencies, and the faster rise time will increase its usefulness in pulse circuit investigation.

The ingenious extendible light hood, formerly supplied as an extra, is now standard with both S42 and S42A.

100μV

PA2 Twin Channel Pre-amplifier

A high-gain pre-amplifier capable of increasing sensitivity by 100 on each independent channel, intended for applications which need exceptionally high sensitivity in, for example, the medical, biological and electro-mechanical fields. The power supply is self-contained, and gain is stabilised against variations in supply voltage. The PA2 may be switched out of circuit, allowing direct input to the oscilloscope without disconnecting.

TELEQUIPMENT

*'Serviscope' is the registered trade mark of Telequipment Ltd., 313 Chase Road, Southgate, London, N.14. Fox Lane 1166

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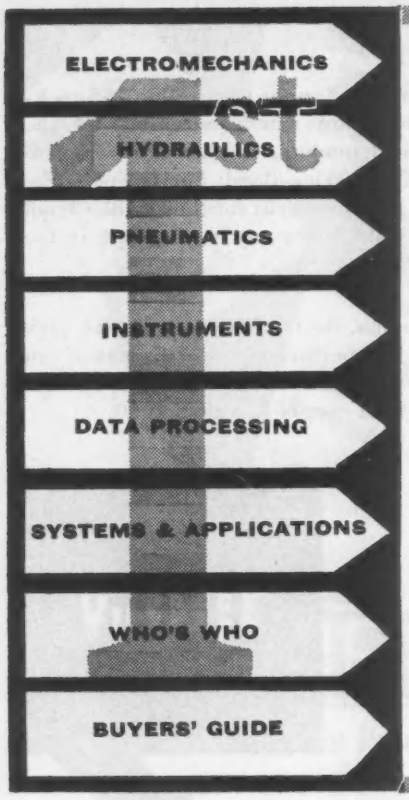

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(An introductory subscription to CONTROL is only £1.10.0)

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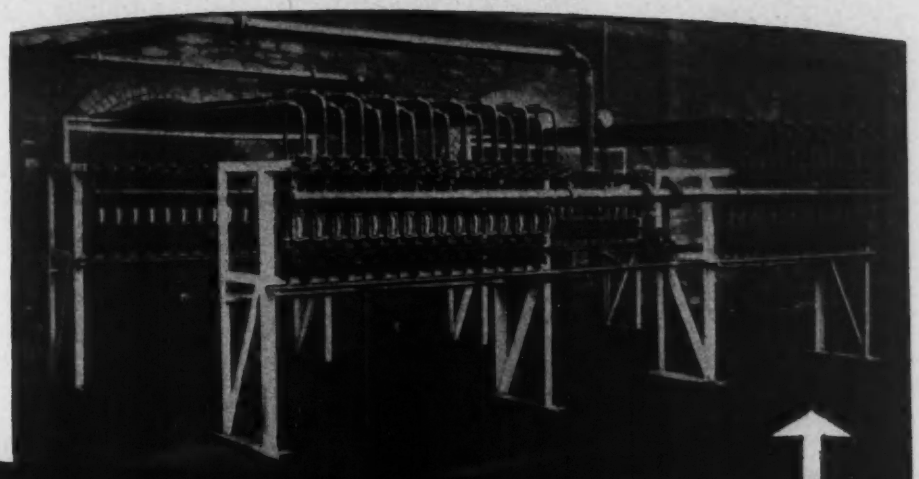
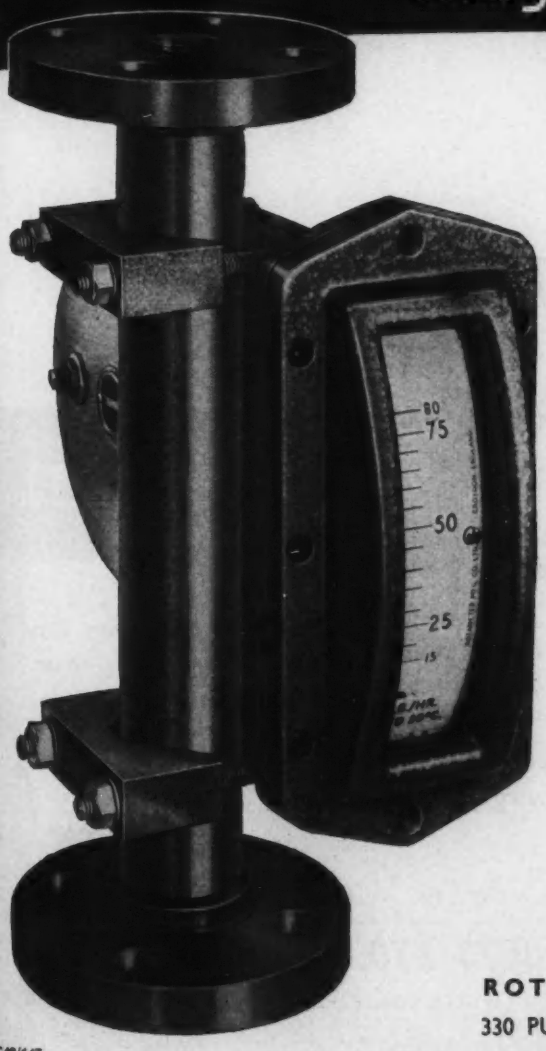
London Sales Office: Magnet House, Kingsway, W.C.2. *Tel:* Temple Bar 4668
A Subsidiary of THE GENERAL ELECTRIC CO. LTD. OF ENGLAND



CONTROL OF P.F.D. INJECTION ...by ROTAMETERS



This impressive battery of 64 Rotameter flowmeters Type 515, installed at the Stapleton Road, Bristol works of the South Western Gas Board, is for the efficient control of petroleum flash distillate injection to the Woodhall Duckham retort House.

Type 515 Rotameter was specially designed for this duty. Relatively low in cost, Type 515 is of all-metal construction, built to withstand pressures up to 750 p.s.i. It uses a metering element of special design, which for cleaning purposes can be removed without dismantling the complete instrument—a valuable aid to easy, speedy maintenance.

To date 300 of these instruments have been supplied to the South Western Gas Board, of which 160 are in use at the Stapleton Road Works.

● *Information on Rotameter Type 515 will gladly be given on request.*

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FLUID MEASUREMENT AND CONTROL
FLOW — DENSITY — LEVEL

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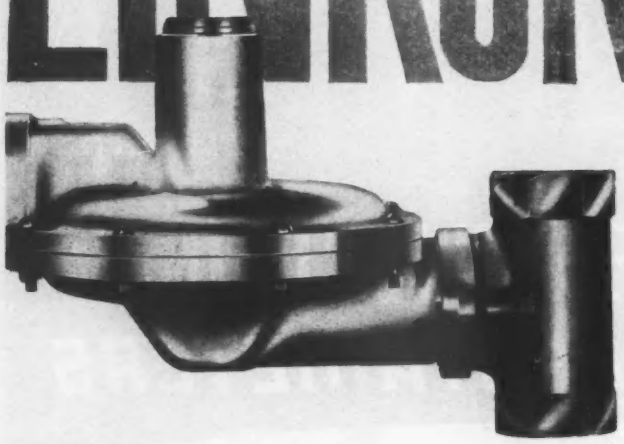

HIGH PRESSURE GAS SERVICE REGULATOR

This regulator is mass produced in a number of different types to suit individual requirements utilising generally the same main components.

The regulator is primarily used for controlling the gas supply from high pressure mains to domestic premises, and is usually fitted with an internal valve safeguarding the meter.

The 'R' Type can be supplied to suit inlet pressures up to 100 p.s.i.

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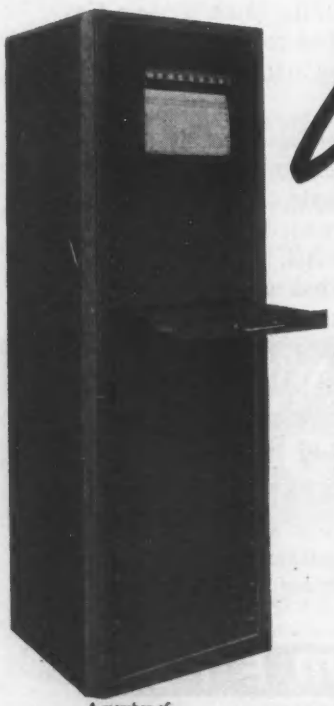

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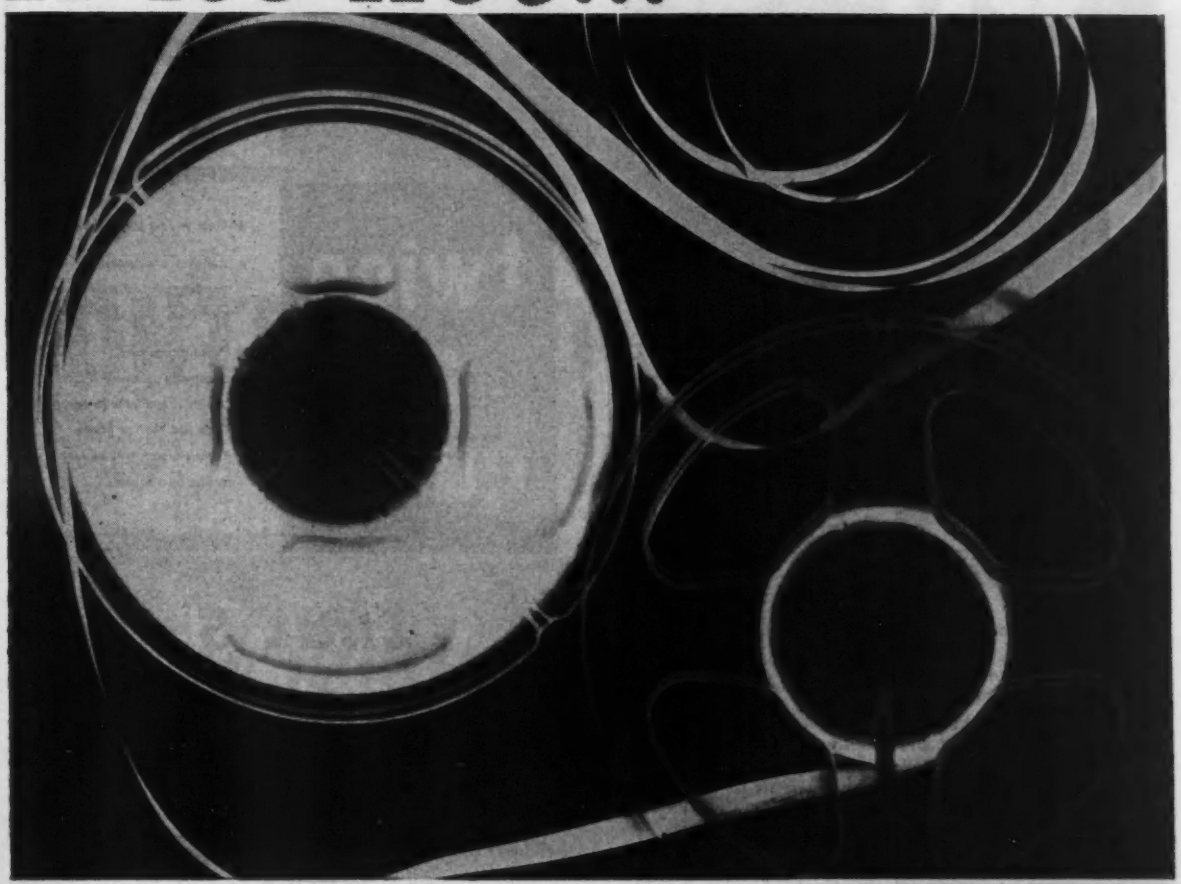

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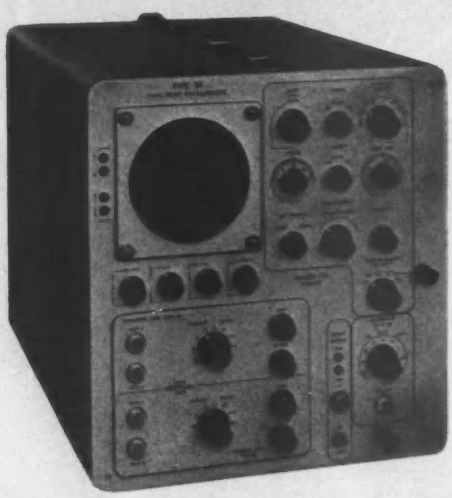
two channel oscilloscope

MODEL **311**



For research needing the display and measurement of low level signals.
Maximum sensitivity 100μV/cm response d.c. to 150 Kc/s.
Calibrated and highly stable Y amplifier gains.
Wide range Time Base directly calibrated in time/cm from 12·5 sec to 1 μsec/cm (2% accuracy) continuously variable.
Independent or common X shifts in two channels, **one being calibrated in degrees for phase displacement measurement.**
X-Y displays on one channel from the two Y amplifiers.

Plug-in Pre-amplifiers
of various characteristics may be inserted, one of which provides a maximum sensitivity of 100μV/cm and includes differential inputs with 10 megohms impedance and good discrimination.
Highly stabilised against mains variations.
Square wave calibrator incorporated, enabling Y amplifier gains to be set up accurately for voltage measurement within 3%.

This instrument represents a major advance in the design of highly sensitive d.c. two-channel oscilloscopes, derived from years of experience in this specialised field.

Ideal for investigation of servo systems of all types, and for stress display.
Versatility, reliability and accuracy.

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twice as good

- ★ Combines high speed fixing with simplicity and security.
- ★ Brings a new versatility, compactness and neatness to your wiring.
- ★ Completely insulated and suitable for all climates.
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- ★ Cuts wiring time by 52%
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- ★ Proof of the way Cradleclip saves time and money is available in our Time and Motion Study Report which will be sent to you on request.

. . . that's cradleclip

"Cradleclip" is a Trade Mark the property of Insuloid Mfg. Co. Ltd.,

. . . and the reason for the phenomenal success throughout the world of this revolutionary wiring system. The one-two . . . and it's done slickness of Cradleclip together with all it's other outstanding features bring new standards of efficiency at every stage of switchgear production and wiring contracts.

The cradle sizes give a wide scope of cable carrying capacity, and Cradleclips are so strong there's no wastage. Ask anyone, from Managing Director to Sweeper-up, and they'll tell you *"Twice as good, twice as quick—that's Cradleclip"!*

one-two and —it's done

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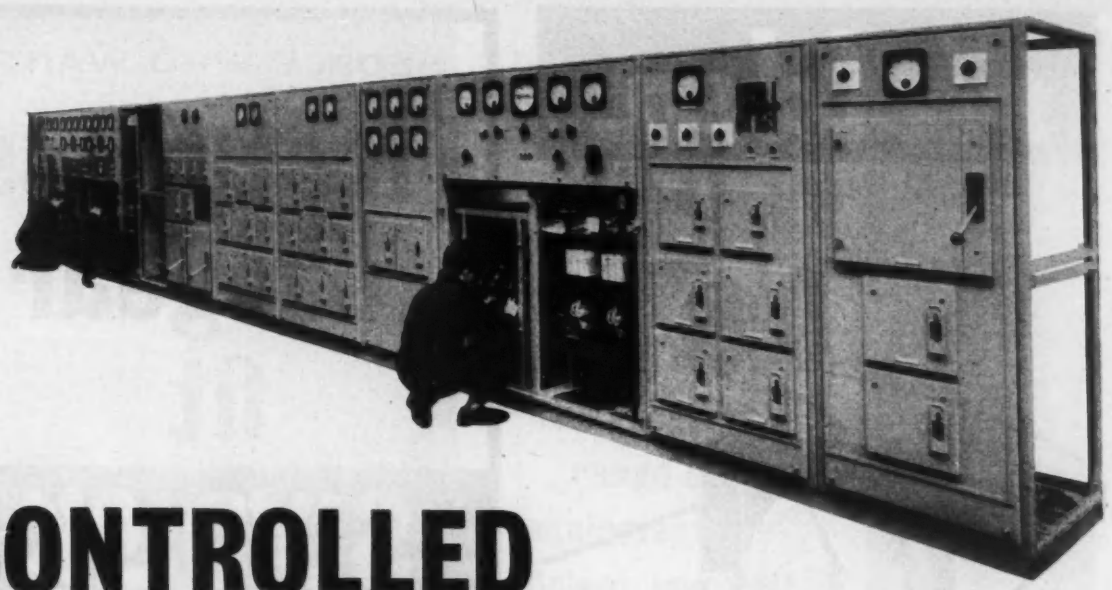
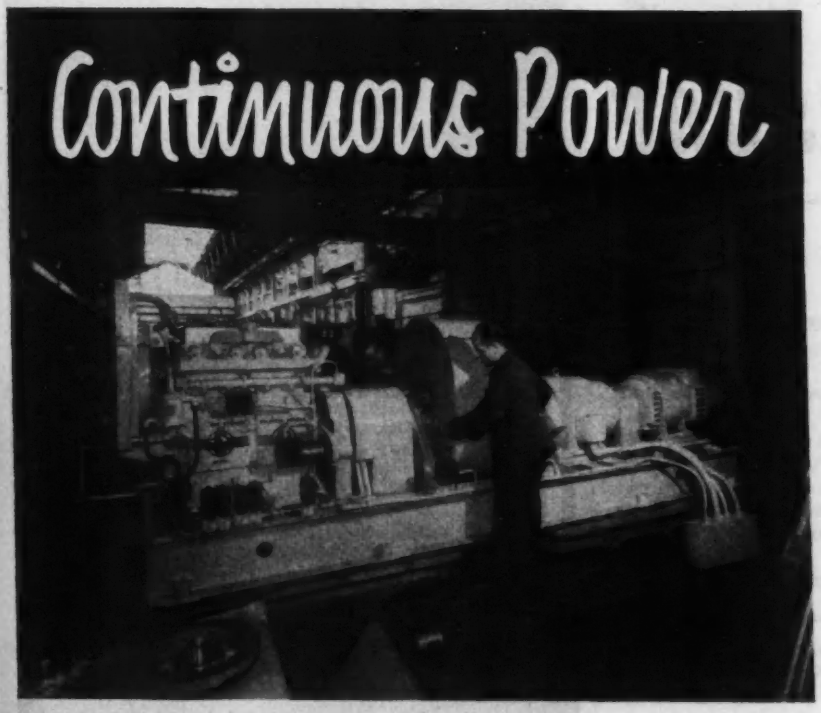
Sharston Works, Leaston Avenue, Wythenshawe, Manchester 22. *Tel.: WYThenshawe* 2842 & 3163



CONTROLLED POWER...

Multi-duty switchboard for new signal box at London Road, Manchester.



25 kVA 'No-Break' generating set undergoing test prior to despatch from the Derby Works.

Fifty years experience has endowed PELAPONE with an unrivalled ability to devise, design and develop automatic equipment * for the generation and control of electrical power . . . equipment which, today, is earning the confidence and approval of engineers everywhere and maintaining the PELAPONE motto:
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***Generating plant, including the renowned PELAPONE No-Break sets, cater for *all* requirements up to 400 kVA. Control equipment for power plant and process systems, ranging from simple engine-mounted panels to multi-duty switchboards and completely integrated control systems.**

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FOR . . .

Steam and other gases.

Water, oil and other liquids.

Pressures down to 5" WG and up to 15000 p.s.i.

Indicating, recording or controlling or any combination of these features.

Vacuum, absolute and differential pressures as well as the usual gauge pressures.

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WITH . . .

Accuracies as high as 0·5% on potentiometric instruments

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★ *Write for comprehensive Remote Pressure brochure C.*

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First class fusegear fit

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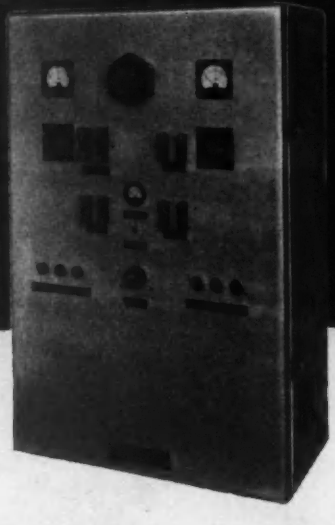

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— from 5 to 100 amps

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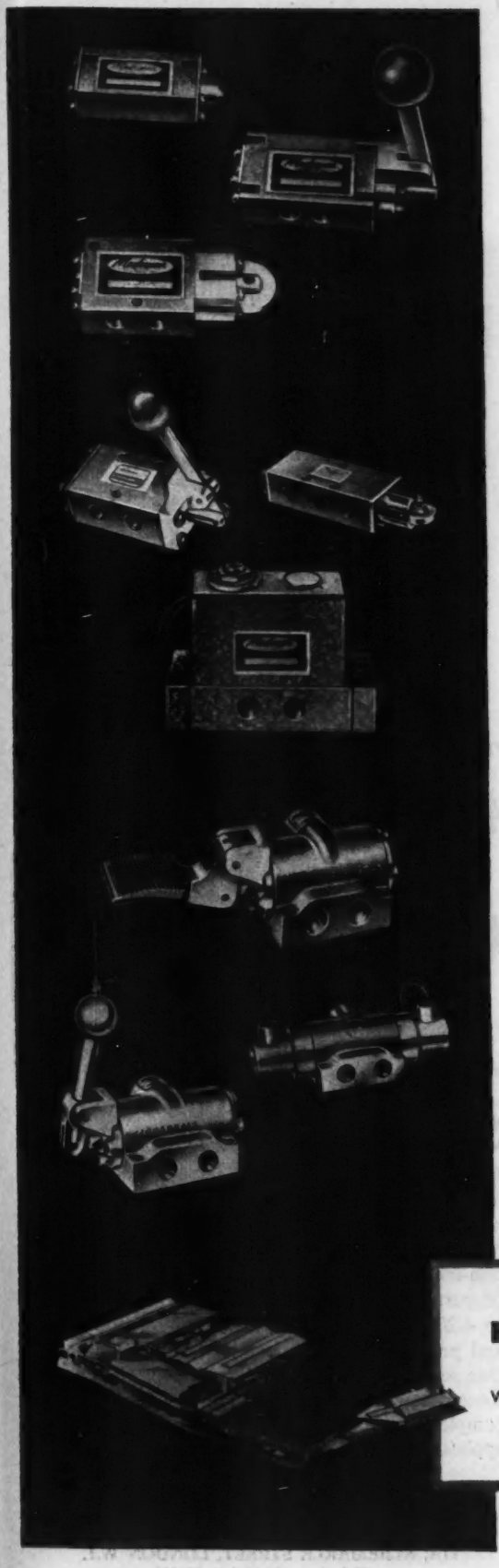

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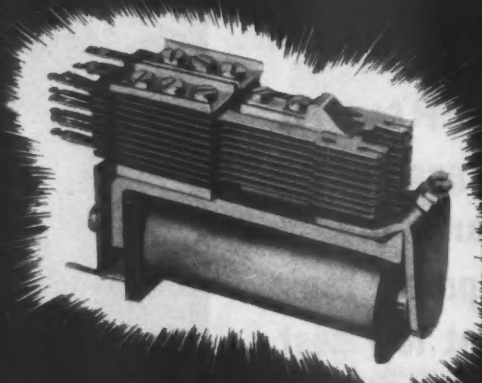
K 3,000 type RELAY



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3000 type RELAY
WITH TRANSPARENT DUST COVER
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Now supplied as follows:-

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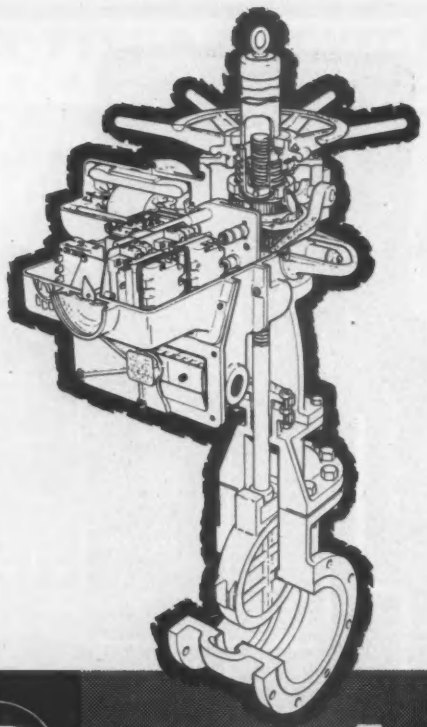

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The Rotork 'A' range of actuators in standard form meets most requirements but can also be supplied to comply with any industrial or national specification. The range covers the power requirements of every type or size of valve.

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MANUFACTURE, SALES & SERVICE.
Highly competitive prices on a world wide scale are assured by manufacturing and sales facilities in West Germany, France and Italy to augment U.K. production, as well as offices or agents in Holland, Switzerland, Australia, Canada, South Africa and the Arabian Gulf.

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Name any big company in a valve-using industry and it is almost certain that you have named a Rotork customer.

Please write for our booklet entitled "ROTORK VALVE CONTROL".

ROTORK ENGINEERING CO. LTD. of BATH, ENGLAND. Tel: 64558

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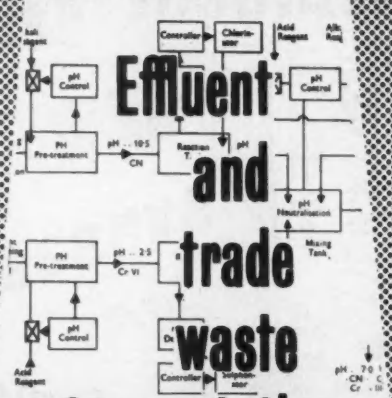

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AUTOMATIC CONTROL for

pH neutralisation of effluent
also
rapid continuous detoxication of trade waste containing cyanide and chromate

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The illustration shows the Servomex AC 2 Mark 2B with wooden ends, these are an optional extra.

£99 in 1953, £99 in 1961

The Servomex AC 2 Mark 2B Voltage Stabiliser is a very remarkable instrument. *Remarkable* because it has held the original 1953 price of earlier models despite increased costs throughout the Industry. *Remarkable* because the materials in each instrument, mostly to military specifications, cost as much as £47. *Remarkable* because 39 man hours go into the production of each unit and the resulting standard product is acceptable to military and government inspectors. *Remarkable* because although ruggedised to stand up to 40g, and tropicalised for service anywhere in the world its price is no higher than for ordinary commercial quality. *Remember* Servomex make only one quality – The BEST that money can buy. Write for Data Sheets and "Notes on Stabilisers" Servomex Controls Ltd. Crowborough, Sussex. Crowborough 1247

SERVOMEX

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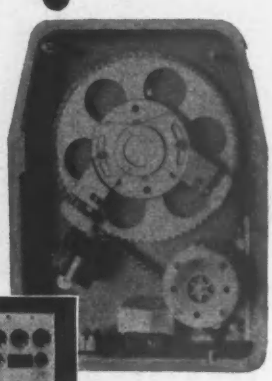
they SIMPLY control

Simplicity in design and operation is a feature of these Tully Actuators. They do a variety of jobs efficiently with the minimum care and attention, often saving the greater expense of pneumatic or hydraulic mechanisms.

With them, if required, we can supply standard control panels for wall or rack mounting, incorporating starter gear, motor protection devices and remote indicating lights.

rotary MK II



Rotary movement up to 300 deg. Torque 90 lb./in. at 1-12 rpm. Lower speeds available down to 0-4 rpm.

Motor 230/250 volt, single phase. Other voltages available. Weatherproof. Adjustable trip arm. Reversible.

linear MK V

Linear actuator. "Hammer blow" effect. Maximum thrust 2,000 lb. Adjustable length of travel.

Emergency hand operation. Maximum stroke 25".

APPLICATIONS

Here are some applications for these Tully Actuators:

Mk. II Butterfly valves, ventilator vanes, lever systems, quadrant valves.

Mk. V Valves, bunker slides, automatically operated traffic control gates, furnace doors.

There are many others, Let us give special consideration to your particular application.

TULLY

actuators

AND CONTROL SYSTEMS

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MOBILE VACUUM STORAGE UNIT TYPE M 410

This robust, easily operated vacuum trolley has proved its usefulness and versatility in the following applications:

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S
E T

solus electronic tubes ltd.

COUNTY BUILDING HONEYPOT LANE
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N.E.P. can now supply everything you need
to make a complete pressure measuring system:

* A 'Packaged' Unit consisting of
Stabilised Power Supply, Amplitude Stabilised Oscillator
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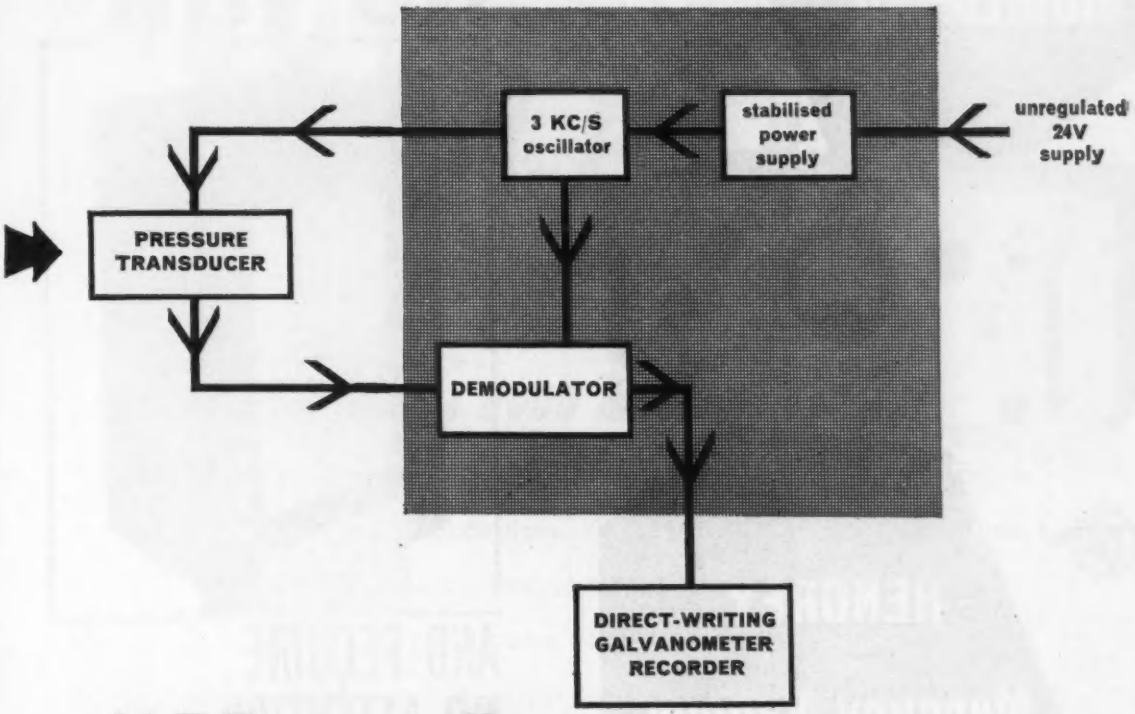

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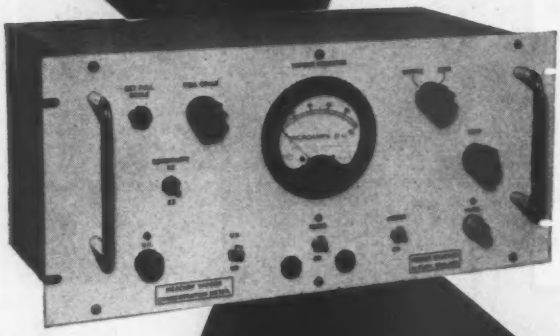
for sampling

and

monitoring



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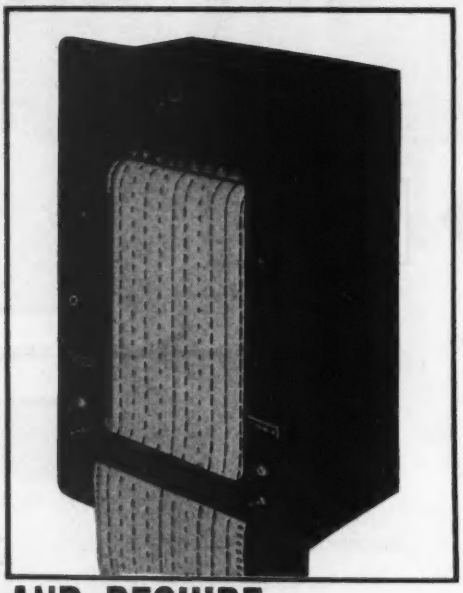

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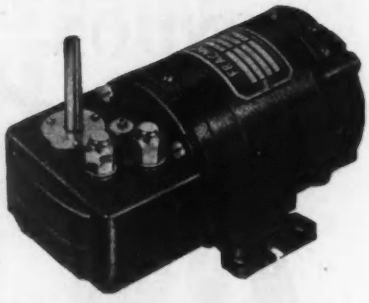

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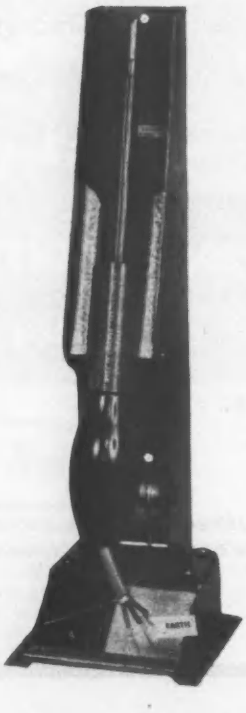
ELECTRICAL SOLDERING EQUIPMENT

Illustrated



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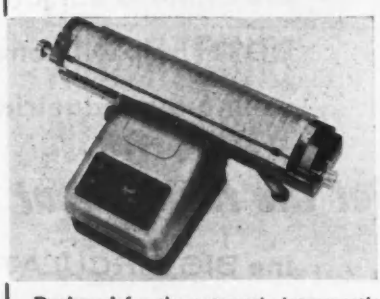
FOR DATA LOGGING AND CENTRAL SURVEY



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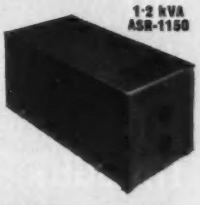

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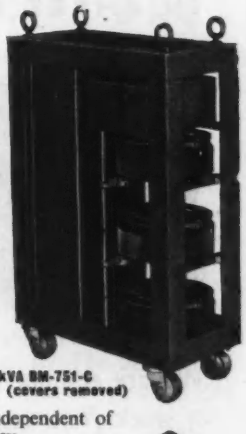

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200 VA TO 94 KVA

- Operation of all types independent of wide variations in frequency.
- Special models manufactured to customers' quantity requirements.

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Claude Lyons Ltd.

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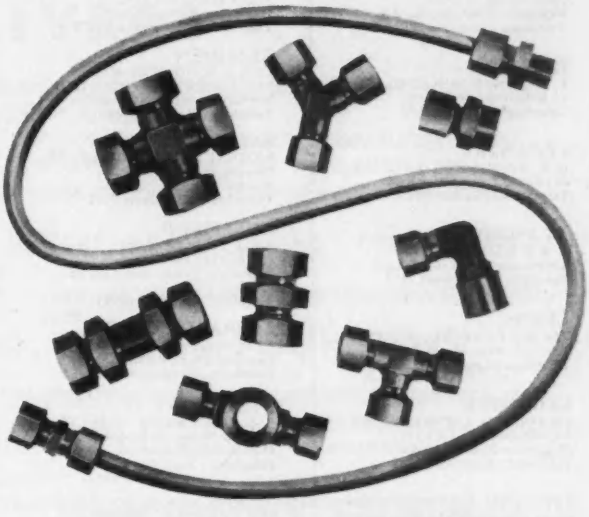

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Simplifix Nylon Tube fittings are dependable, practical and economical. They are easily and quickly fitted. No work is needed on the end of the tube because the specially designed brass olive ensures a perfect seal and prevents the tube twisting when the joint is made. The coupling bodies are the same as those used for copper tube. Olives and securing nuts can be supplied separately. Only one stock of bodies is needed to make up fittings for Copper or Nylon Tube. Simplifix Nylon Tube couplings, olives and securing nuts are available for O.D. tube sizes of $\frac{3}{16}$", $\frac{1}{4}$", $\frac{5}{16}$", $\frac{3}{8}$" and $\frac{1}{2}$". Nylon Tube for these couplings can be supplied in a wide range of colours.

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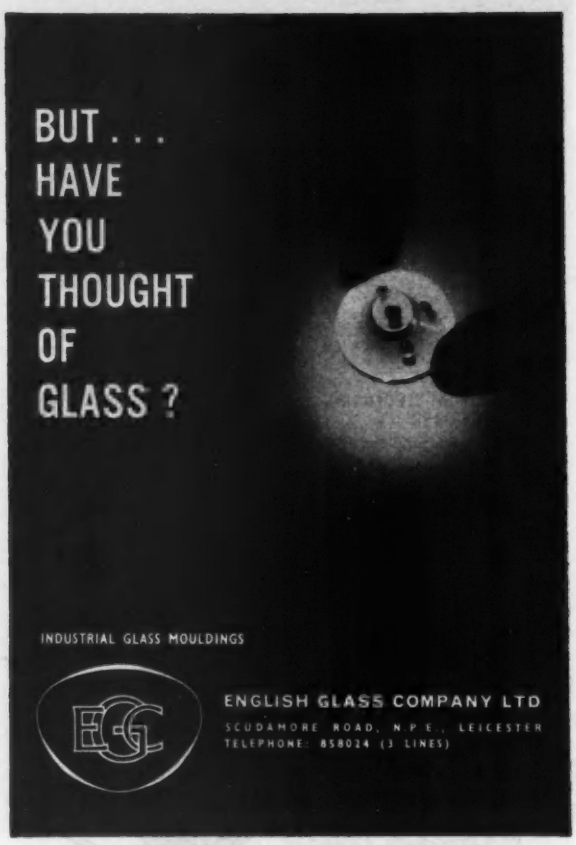

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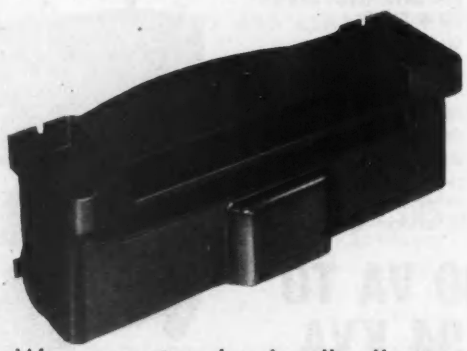

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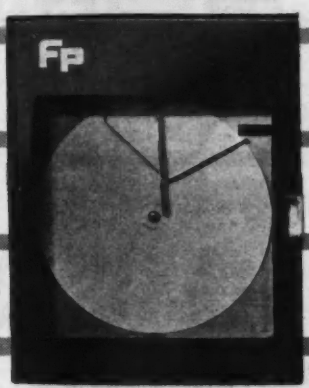

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Comparison of Power Media
Airline Installations
Airline Filter and Lubricator Equipment
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KINETROL *Precision* Dashpot

the **sealed** unit for time delay, vibration and shock damping.

- Purely viscous — no friction
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Adjustable model has calibrated knob to set any desired damping rate 10:1 range. The Kinetrol dashpot is being used with success in many industries on a wide variety of new and existing machinery it could solve one of your problems.

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Manufacturers of Dashpots, Rotary Actuators and Fine Wire Feeders.

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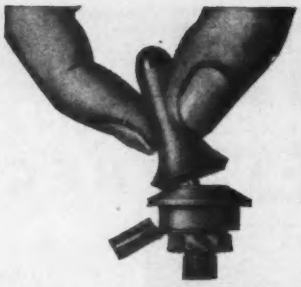

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QUICK RELEASE TERMINALS

For testing problems at low rating and where there is insufficient space to accommodate the larger 15-amp terminal (many thousands of which are already in use) the 5-amp terminal is now offered. These spring-loaded terminals make faultless electrical connections instantly and safely.

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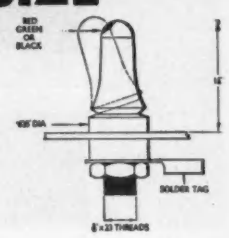

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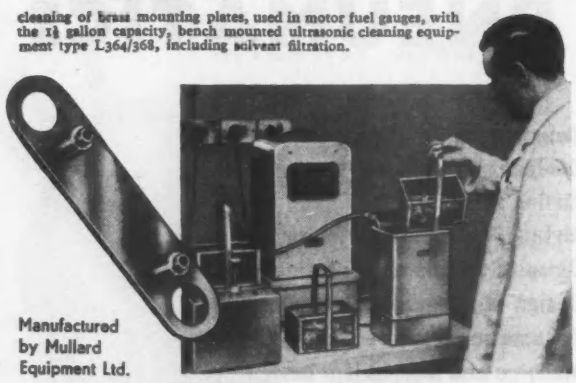
How *ULTRASONIC* Cleaning is serving Industry . . .

. . . AT **SMITHS** MOTOR ACCESSORIES LTD., LONDON, N.W.2

cleaning of brass mounting plates, used in motor fuel gauges, with the 1½ gallon capacity, bench mounted ultrasonic cleaning equipment type L364/368, including solvent filtration.



Manufactured by Mullard Equipment Ltd.

The mounting plate for the motor fuel gauge, has a hole in the centre which is only a few thousandths of an inch diameter. It is important that this hole is absolutely free from metallic swarf, lint, dust, etc. Ultrasonic cleaning provides the perfect solution for the problem. The cleaning is carried out in an organic solvent and a complete work load is handled in approximately one minute.

Kerry's (Ultrasonics) Ltd

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Tel. MARyland 6611. Works: Harold Hill, Romford, Essex
Manufacturers of Ultrasonic Equipment and sole U.K. distributors of Industrial Ultrasonic Equipment by Mullard Equipment Ltd.

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The Stored Energy Capacitor Discharge Controller delivers a precise amount of power to the welding electrodes regardless of mains fluctuation. Energy is stored in capacitors which are charged from a built-in stabilised DC supply. This DC supply is infinitely variable for weld power control and each setting can be reproduced within the limits of 1.5%.
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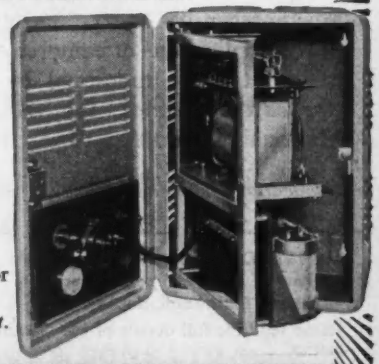

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'Hinged book' construction for easy servicing.

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HIRST ELECTRONIC LTD.
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and machine control equipment

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A Cincinnati Hydrotel Milling Machine fitted with an E.M.I. three dimensional control system. The control circuits employ up to one hundred of our MUMETAL TOROIDAL CORES in the ANALOGUE POSITION MEASURING UNIT and the INTERPOLATOR UNIT. The control is by punched tape.

INTERPOLATOR UNIT showing the use of TELCON MUMETAL CORES.

TELCON METALS manufacture a complete range of MU-METAL CORES in strip THICKNESSES from .0005" to .015", and having outside dimensions from ¼" up to 6¼". Bakelite core cases to protect the material from winding, handling and transit strains are available in a large number of sizes.

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A new catalogue of Thermostatic Bimetals is now available.

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Utilising standard electronic units drawn from the five "COUNTEC" models covering 0.1 sec. to 5 min., a most flexible sequential control system is built up, immediately adjustable by calibrated knobs at any stage without a halt to the process.

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A Dekatron counting system which can either be used to measure an unknown time-period or to time out after a preset delay. Models available range from milli-seconds to minutes.

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Available for chassis mounting or in watertight case, ranges 40, 80 and 120 minutes with built-in mains-operated magnetic clutch for remote control.

Full descriptive literature from the designers & manufacturers of these British made products

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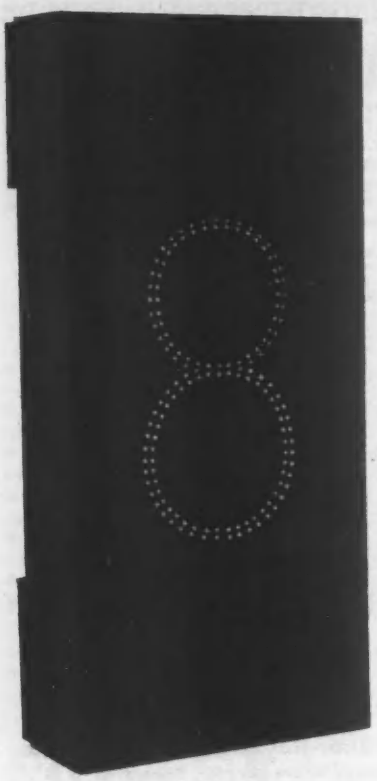

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This indicator provides an ideal method for the selective display of numbers, letters or symbols where a large display is required.

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★ *Adjustable to proportion between 4 to 1 and 50 to 1.*
★ *Accuracy of 1% to 2½% over the range.*
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★ *One or both pumps in acid resistant material.*
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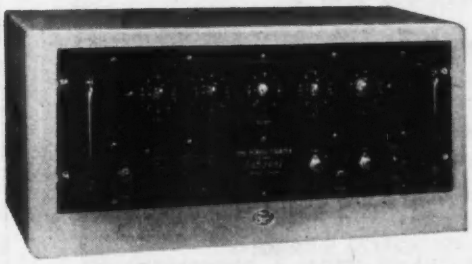
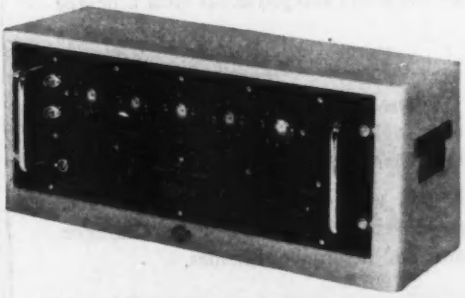
decatronics* .....!

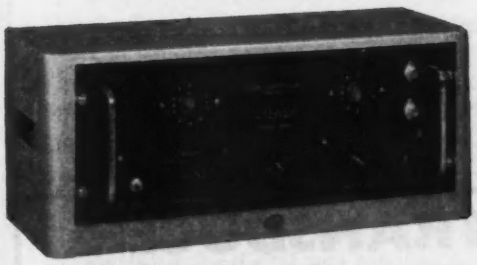
A complete range of Instruments for Pulse Counting and Timing



D.4108 Time-Period Counter for measuring short time intervals between events.



D.4131 Fast Counter for general industrial and nuclear pulse counting.



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To meet the needs of a widening variety of counting and timing functions involved in many industrial processes to-day, Labgear Ltd. offer a range of instruments which combine laboratory accuracy with practical "workshop" reliability. Labgear engineers have devoted special attention to advances in circuit techniques, with the result that each instrument embodies special features and provides facilities for versatility in use.

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* Decatronics — a word not yet in the dictionary, perhaps, but "coined" to designate that class of pulse counting and timing techniques developed around the decade counter tube.

Labgear Ltd.

LABGEAR

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to develop mechanical/electrical Transducers. There is full scope for ability, originality of thought and individual effort.

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to work on circuit development of transistorial control systems for an expanding range of commercial vehicle and railway modernisation projects.

This position carries responsibility for handling projects from inception through to production.

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While successful candidates will be appointed initially to work in this field, experience in other fields will be planned with a view to the achievement of senior managerial positions.

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To encourage and assist the more rapid introduction of automation into the steel industry, the British Iron and Steel Research Association has recently formed a new Control Engineering Section.

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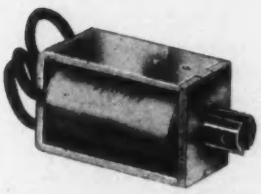

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Book Reviews

Automation

Automation and Skill *by* **E. R. F. W. Crossman.** *D.S.I.R. 1960. 60 pp. 3s. 6d.*

This booklet of about sixty pages is the ninth of a series on industrial problems sponsored by the Department of Scientific and Industrial Research. The purpose of the booklet is to discuss the new issues raised by automation techniques so far as they reflect the changing pattern of requirements for human skill. The report is based on visits to widely different factories, including plants manufacturing motor-cars, valves, cigarettes, textiles, paint, biscuits, margarine and heavy chemicals, in all of which there is some degree of automation. Automation is considered to be divided into three types; continuous-flow production, use of programmed machines, and centralized remote control. The most impressive findings relate to plants in continuous-flow production. In these there is a tendency to require control and communication skills and to produce a new type of preventive-maintenance routine worker. The chief requirement for the former is *decision*, i.e. selection of the best control action for each combination of circumstances that arises.

There appears to be a considerable variation in control skill: less effective operators tend to work by rule-of-thumb and better ones by intuitive appreciation of the whole state of a process, possibly by making a mental working model. This is a rather fascinating conclusion. Designers of highly automated systems have a similar choice between basing systems on 'automated rule-of-thumb technique' or going the whole hog to create a genuine electronic process-model to which all automated decisions can be referred. In spite of a lot of talk about self-optimizing computers the present evidence, according to my experience, is that most practical automation systems are 'automated rule-of-thumb'. It might be worth while for some of our electronic companies studying the application of computers to processes to investigate intensively how good human operators come to their control decisions, since it may be that the human psyche has remarkable resources for making 'process model pictures'. According to the report under review, process operators can sometimes achieve better results than a trained engineer thinking logically about control problems: it appears that there is no rational approach to very complicated events and that some degree of intuition is essential.

Repetitive manual jobs tend to be substantially abolished in automated production, but they reappear under the cloak of planned maintenance. This emphasizes the difference between the type of work done by preventive-maintenance crews and shift-maintenance staffs. The latter must be able to deal rapidly with unforeseen break-downs, and may need diagnostic skills of a high order.

Whilst this short report only sketches the outlines of the problems, it appears to be a very valuable contribution. It could be studied to advantage by both automation users and equipment suppliers.

D. B. FOSTER

Rockets

Kinetics, equilibria, and performance of high temperature systems. *Edited by* **Gilbert S. Bahn** *and* **Edward E. Zukoski.** *Butterworths Scientific Publications Ltd. 1960. 255 pp. £4.*

This book gives the proceedings of the first conference on the subject of the title, which was held by the Combustion Institute in Los Angeles from the 2nd–5th November, 1959. The conference was sponsored by the Marquardt Corporation and by Rocketdyne, and supported by the Air Research and Development Command. A small amount of confidential work presented at the conference is not included in the book.

From its origins it would appear that the subject of the book is highly specialized and the high-temperature systems considered are without exception rocket motors. The papers in fact cover exhaustively, and with a great deal of repetition, the problem of calculating the performance of a rocket engine. The majority of the papers are concerned with calculations of the thermodynamic performance.

For control purposes the most interesting part of the book will be that on kinetics and on instrumentation. Unfortunately this part of the book is slender and not of obvious use for control. There are, for example, papers on a combustion model with droplet break-up, and studies of chemical non-equilibrium in hypersonic flow nozzles. The emphasis here is strongly upon engine performance. The one paper on instrumentation is entitled 'Criteria for design and development of automatic, self-linearizing, self-editing, electronically calibrated transducers'. The hopes aroused by this comprehensive title are disappointed in the performance. The paper considers at arm's length a number of possible techniques, and ends with a recommendation for a literature study.

To sum up, the book is of only marginal interest from the point of view of automatic control. Apart from its own specialized field of rockets it may be consulted by those concerned with equilibrium in high-temperature chemical systems. It presents a great deal of experience in the calculation of chemical equilibria in these systems. It also presents considerable experience with computer techniques for solving sets of non-linear equations or for finding the minimum of a function.

The production of the book is good, though the level of technical writing is often low. An example, not by any means unfair, is the following:

> An extension of event counting concepts leads to regional boundary transducers. Essentially, the boundary for a region may be detected by an event counter. Such a sensor may be considered as a type of narrow band filter. The actual physical parameter indicated must be recognised in two senses. First, a boundary crossing must be sensed. . . .

Here and in many similar places a vigorous use of the editors' pencil would have improved the book.

H. H. ROSENBROCK

Russian

Translation from Russian for Scientists *by* **C. R. Buxton** *and* **H. Sheldon Jackson.** *Blackie & Son Ltd. 1960. 299 pp. £1 10s.*

Soviet technical literature is both extensive and important, and though some of it is translated, most is available only in the original. To read Russian technical papers without much hard labour needs a thorough mastery of the language, which few engineers have the time or the opportunity to acquire. Even a more superficial reading knowledge of Russian however, is very useful and this book is specially designed to enable the student to acquire this easier accomplishment.

The volume starts with a section on grammar. This provides an excellent introduction to the Russian alphabet, the first obstacle in the way of the English student. The grammar is clearly and compactly presented and backed by illustrative translation exercises, but for the beginner the section may well prove difficult; more and simpler exercises would have been welcome. The book is completed by a good selection of Russian texts with a short vocabulary. These are designed for the physicist and chemist, and the control engineers will not find their special interests catered for.

In learning a language there is no substitute for a teacher. As a textbook for use under guidance this work will be very useful, but a student who wishes to learn Russian on his own with the aid of this volume alone will find it a very formidable task.

L. FINKELSTEIN